Business Process Modelling and Simulation with Application to a Start-up Actuarial Firm

Student : Tatenda Mark Gweshe
Supervisor : Dr Leanne Scott

Abstract

In our research, we set out to model, understand and evaluate the business process at a start-up actuarial firm which employs Report Writers (RWers) who specialise in quantifying actuarial matters. We simulated various “what-if” and extreme scenarios relating to (1) the impact of qualitative variables (stress, morale and health) on RWer productivity, (2) hiring policies for RWers who have various skills sets, (3) the allocation of RWers to various roles within the process, (4) the impact that a high turnover of experienced RWers has on productivity, (5) the impact of introducing a flexible working arrangement (flexitime). This was done through business process modelling and simulations.

The business process we modelled was governed by numerous potentially complex inter-relationships between variables and inter-relationships, which we believed could lead to potentially significant feedback loops. The models we built were then simulated over a period of 3 to 7 years to gain insights into the behavioural trends of the firm’s business process over time when subject to “what-if” scenarios and policy implementations. The model simulations allowed us to get an understanding of the behaviour of processes over time, and the key variables and relationships involved in bringing about such behaviour as certain variables were subjected to changes in levels, as set out in our objectives.

We made use of relevant literature, expert opinion, past data, questionnaires and cognitive mapping techniques to build simulation models. Guided by methodologies used in literature on modelling qualitative variables, bearing in mind the dangers in modelling for them, we modelled for the complex inter-relationships between qualitative and quantitative variables.

In addressing our first objectives, the model simulations revealed how a drastic negative change in employee wellbeing (health, morale and stress) has a significant impact on a RWer's work output. The simulation of the hiring process of RWers revealed how the size of the workforce has a great impact on work output and employee wellbeing. With regards to the simulation of RWer allocation, we observed how allocating RWers to roles that will bring about an improvement in productivity may not necessarily result in the best state of employee wellbeing (health, morale and stress levels). Our assessment from analysing the continuous turnover of experienced RWers revealed how fluctuations in workforce wellbeing and differing skills set, brought about via new recruits, has a significant impact on RWer productivity and employee wellbeing, putting a significant strain on the firm as it tries to meet deadlines. Similar conclusions were reached in our analysis of RWers on flexitime, with the boost of morale not being realised in RWer productivity due to them continuously being out of the office.

Our research revealed the usefulness of business process modelling and simulation in analysing complex processes and highlighted the dangers of relying on mental modelling and/or schematic diagrams only.

Plagiarism Statement

I know the meaning of plagiarism and declare that all of the work in the dissertation, save for that which is properly acknowledged, is my own.

Signature:

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Glossary of Terms

Actuarial Reports

Reports quantifying (1) Motor vehicle accidents/Road Accident Fund Matters/3rd party claims (loss of income and loss of support), (2) Divorce and estate claims (calculation of maintenance), (3) Medical malpractice claims, which are drafted, checked and sent by Report Writers.

JRWer

Junior Report Writer. Not studying towards actuarial qualifications.

JRWDFTer

Junior Report Writer who strictly drafts actuarial reports.

RWer

Report Writer. Either a JRWDFTer, SRWCHKer, JRWSNDer or SRWSNDer.

SRWer

Senior Report Writer. Studying towards actuarial qualifications.

SRWCHKer

Senior Report Writer who strictly checks actuarial reports.

JRWSNDer

A Junior Report Writer who strictly drafts and sends his/her own actuarial reports.

Flexitime

Flexible working arrangement for JRWers.

MTProdDTQLVs

Multiplier to productivity due to qualitative variables.

MTProdDTH

Multiplier to productivity due to health.

MTProdDTM

Multiplier to productivity due to morale.

MTProdDTS

Multiplier to productivity due to stress.

MTProdDTQ

Multiplier to productivity due to quality.

MTHDTexh

Multiplier to health due to exhaustion.

MTHDTov

Multiplier to health due to overtime.

MTHDTsick

Multiplier to health due to sickness.

MTHDTstress

Multiplier to health due to stress.

MTMDTjobsat

Multiplier to morale due to job satisfaction.

MTMDTflex

Multiplier to morale due to flexible working arrangement.

MTMDThealth

Multiplier to morale due to health.

MTMDTsupport

Multiplier to morale due to support.

MTSDTwcap

Multiplier to stress due to work capacity.

MTSDTsupp

Multiplier to stress due to support.

MTSDTleisure

Multiplier to stress due to leisure.

MTSDTjobstress

Multiplier to stress due to job stress.

MTSDTurgent

Multiplier to stress due to urgent tasks.

MTQDTM

Multiplier to quality due to morale.

MTQDTstress

Multiplier to quality due to stress.

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1. Introduction

1.1 Research Background

The aim of our study is to showcase that business process modelling and simulation is an adequate approach in studying what we perceive to be a complex business process. Using this approach we aim to evaluate different policy implementations and "what-if" scenarios such as the impact of qualitative variables (health, morale and stress) on productivity and the impact that continuous turnover of employees has on the process as a whole. From the modelling and evaluation of the process we intend to get a valuable understanding of the key variables and structures governing the business process.

The process of a business involves a consumer (client) approaching a supplier (firm), wishing to purchase a certain product or service. The supplier then manufactures and produces the service for the consumer (Mentzer, et al., 2001). Furthermore, typically in relatively small firms, when it is time to evaluate their business process, management get together for a brainstorming session and point out areas in the business process they are doing well in and areas where they can improve. They discuss measures they can put in place to maintain the level of service and measures they can adopt to improve where improvement is necessary. The discussions usually do not go beyond the form of mental modelling, which entails them modelling, evaluating and understanding the business process according to how they see it working. However, the process could potentially be more complex in nature when studied in more detail, with the complexity derived from numerous variables interacting with each other through various feedback structures within the process. Attempting to mentally model, evaluate and understand each significant variable and their cause and effect relationship amongst each other may prove to be impractical, with management likely to overlook important variables or not take into account certain significant dynamic relationships between variables. This is mainly due to management's oversimplification of a complex process as well as limited perspective in certain areas of the business process (Hall, 1976).

We study a small firm's business process, starting from simple modelling of its business process and gradually unveiling its complexity as a whole in order to draw insights into our set objectives. In our case, the small firm we evaluate in its complexity is a start-up actuarial firm, which employs report writers (RWers), which provides actuarial reports for its clients who are attorneys. We define a complex process as having feedback loops, inter-relationships and other effects that have an impact on the entire business process (Repenning & Sterman, 2002). In such a case a rigorous form of business process modelling is required. For our research, we use business process models and simulations to evaluate and understand the business process at the firm. We make use of relevant literature, expert opinion, and cognitive mapping techniques to help set the objectives of the study and build simulation models that are tailored to the objectives.

Before building and simulating the models, we perceive that a significant source of complexity in this business process comes from the effect of qualitative variables, such as health, morale and stress, on RWer productivity. Through model simulations, we will undertake to see if a hypothesised set of inter-relationships between qualitative and quantitative variables, including some feedback loops, have a significant impact on the behaviour of the business process. The core structure of the model shall be built from data and information gathered from RWers. The data and information is gathered by conducting meetings with them and collecting data and information through questionnaires and discussion sessions. This data and information also helps us get a sense of the dynamic structures and inter-relationships governing the business process. We also make use of cognitive mapping to gain a strategic perspective of the business process with regards to how it came to be and how management believe it will evolve over time. The information gathered from the cognitive mapping sessions with management is also meant to help us ensure that the models we build will be able to answer the kinds of questions management have about the current running of the business and assist them to make decisions in the near future.

1.2 Simulation using a System Dynamics Approach

The system dynamics (SD) approach is used to get an understanding of the behaviour of a real world system through the use of models that account for the inter-relationships and dynamic feedback structures that govern the system as a whole (Hall, 1976). The approach deals with the technique of quantitatively, and qualitatively, modelling complex and problematic situations so as to understand them (Eden, 1994). The SD approach began in the 1950s when it was developed to assist corporate managers in improving their understanding of industrial processes (Forrester, 1997). Over time this approach has been adopted by many businesses, such as General Motors OnStar, where the methodology was used to assist in strategic decision making in marketing GMs OnStar product (Barabba, et al., 2002) and Du Pont where SD helped the company understand the dynamics behind its ineffective quality management program (Repenning & Sterman, 2001). In this dissertation we wish to use it in a similar way to help us model, understand and evaluate the business process at an actuarial start-up firm. The model will be built and simulated using Vensim simulation software, which allows the modeller to model complex inter-relationships (including potentially significant feedback loop), as well as detect key variables and inter-relationships governing the behaviour of the business process. This allows the modeller to get a better understanding of the behaviour of the business process over time (including behavioural trends).

1.3 Cognitive Mapping

We set out to use cognitive mapping in this research to get a better understanding of the current business process and future growth path of the firm. As the model is built and developed, we wish to incorporate the relevant goals and aspirations of stakeholders involved in various parts of the business process. The cognitive map based on management's perspective helps us to identify what they consider to be the key areas in the business process and how they see the firm growing over time, which provides us with a basis to formulate the objectives of the study. In Chapter 4, the sub headings *General Background* and *Objectives set out* under each objective in that chapter are therefore based strongly on key findings from the cognitive mapping. Management are the key policy makers and implementers, and are considered to be the most informed with regards to the growth path of the firm, mainly regarding forecasted workflow and required human capacity.

1.4 The Start-up Actuarial Firm

Product and Service

The start-up actuarial firm, from here on described as the firm, provides the following forensic actuarial services: (1) motor vehicle accidents/Road Accident Fund Matters/3rd party claims (loss of income and loss of support), (2) divorce and estate matters (calculation of maintenance), (3) medical malpractice, as well as services in calculations of loss of interest and equity growth, small business assessments, testifying as an expert witness in High Court and quantification of general damages reports.

About The Firm

The firm is a fast growing business having grown from less than 15 employees prior to 2012 to over 40 employees by the end of 2014. It is now a leader in its market with regards to providing quality actuarial products and services, with its core values centred on the quality of the product and service, and swift turnaround time of product and service delivery.

1.5 Objectives of Study

Through business process modelling and model simulations, we set out to understand the firm's business process with the intention of gaining valuable insight into the process and the key variables, structures and relationships governing it. We also analyse and evaluate the impact of various "what-if" scenarios. Although it is evident that the growth of the business in its market heavily depends on quantitative variables such as the timely delivery of reports to clients, we also want to investigate the impact of qualitative aspects such as health, morale and stress on employee productivity. The qualitative variables, and their interactions amongst themselves and with quantitative variables, are likely to form the core of potentially significant feedback loops within the system. The objectives of the paper are summarised below, but to be discussed in more detail in Chapter 4 – Objectives and Methodology.

We aim to showcase how we can adequately address, and gain insights into, the objectives below through the use of model simulations:

1. The impact that qualitative variables have on RWer productivity and on the business process as a whole.

2. "What-if" scenarios around the initial hiring of RWers given the expected growth of the business over time.

3. Understanding the implications of allocating RWers into different roles as a means to improve productivity and the working environment.

4. "What-if" analysis around the continuous turnover of experienced RWers and the impact it would have on firm productivity over time as the firm attempts to replace experienced RWers with new RWers with varying skills set.

5. The impact that the introduction of a flexible working arrangement would have on RWers' productivity and well-being.

As we address each objective through model simulations, we also take note of the potential impact that feedback structures in the firm's business process have on the behaviour of the process.

What makes this research novel is that it deals with a unique real-life business that has only just recently started to expand its firm size, productivity and client-base. The analysis does not just make use of quantitative variables, but also investigates the impact that qualitative variables have on the process as a whole. The interactions amongst the quantitative variables, as well as the interactions between qualitative variables and quantitative variables with the rest of the process, make for a potentially complex business process. Where applicable, it is envisaged that the actual findings from this research will lead to improvements in the real-life business process.

1.6 Limitations of the study

It must be stated that not all variables and aspects that significantly affect the business process at the firm can be captured. Furthermore, the data required for an accurate measure of certain variables governing the process may not be available. In the case where data is not available or cannot be captured, the use of expert opinion from stakeholders at the firm shall be used to come up with plausible estimates.

1.7 Thesis Structure

We begin the dissertation with Chapter 2, which will review literature on business process modelling techniques, the use of SD as a modelling approach, as well as modelling qualitative variables in relation to business processes. We also look at case studies where SD has been used. Furthermore, we take a look at literature on cognitive mapping with reference to capturing management's strategic view of the business to ensure our model is relevant to their needs.

Chapter 3 then reviews the general model, and gives an account of the different stages in the model building and development. This includes workshops with various stakeholders in the firm assisting us in collecting data and information about the business process. We describe how the process began with a simple model which grew in complexity over time as more information was made available and our understanding of the process deepened. Chapter 4 delves into the research objectives and methodology. Here we outline the objectives and the step-by-step methodology we will use in answering the objectives. Chapter 5 is the results section which provides the key results from simulating the objectives set out in Chapter 4. We then discuss and conclude our findings in Chapter 6 and Chapter 7 respectively.

2. Literature Review

2.1 Overview

This chapter firstly reviews different modelling techniques used to study business processes. Giaglis (2008) documents the various methods used for Business Process Modelling in his journal article titled “A Taxonomy of Business Process Modelling and Information Systems Modelling Techniques.” We use his literature, along with other supporting literature, to explore the various modelling techniques that are useful in business process modelling. We conclude by establishing why SD is the most appropriate modelling technique for our research given a list of other business process modelling techniques that includes Flowcharting, IDEF techniques, Petri nets, Knowledge-based techniques and Role activity diagramming. We look at the characteristics of each of these modelling techniques, their uses as well as their limitations in business process modelling.

Once we have established the SD approach as an adequate technique that will aid in modelling, understanding and evaluating the business process at the firm, we will then go into more detail about the SD approach. We take a look at the history of SD from its conceptualisation by Jay Forrester, the founder of the SD approach. To give context to its application, we explore two pertinent case studies employing the SD approach, namely in the journal articles titled “A System Pathology of an Organisation: The Rise and Fall of the Old Saturday Evening Post” by (Hall, 1976) and “Modelling a Biotechnology Start-up Firm” by (Morecroft, et al., 1989). The two case studies relate to the approach we wish to take in building the firm’s business process model. The section that follows discusses the literature on modelling qualitative variables, with the focus being on outlining the adequacy of incorporating qualitative variables into the business process we plan to model. The last section in this chapter reviews literature on cognitive mapping in the context of business process modelling.

2.2 Business Process Modelling

Literature on business process modelling has shown that there are numerous techniques available to modelling business processes. Giaglis (2008) provides a framework for evaluating adequate business process modelling technique given the modellers goals and objectives. In his journal article titled "A Taxonomy of Business Process Modelling and Information Systems Modelling Techniques", he reviews the following modelling techniques:

1. Flowcharting
2. IDEF techniques
3. Petri-nets
4. Simulation (System Dynamics)
5. Knowledge-based techniques
6. Role activity diagramming

We review each of these techniques to determine which would be the most adequate in modelling the business process at the firm and assist in answering the objectives most adequately.

2.2.1 Flowcharting Overview

Flowcharting is a graphical modelling technique used mainly to visualise a process and aid in coming up with suitable solutions or bring clarity to problematic areas within the process. By having a visual of the process as a whole management are better able to understand and evaluate how certain changes to subsections in the process will affect the process as a whole given interdependent relationships of variables within the process (Gilbreth & Gilbreth, 1921).

Flowcharts have been useful in the design of computer programs, making it easy for people to write a program or code, as well as to explain the program to others. For example providing visual aid to explain how a certain programme will meet intended IT requirements of a business. The ease at which stakeholders grasp the business process through flowcharts makes flowcharting a useful technique for assists in communicating processes that may be relatively difficult to explain or follow (Rosemann, 2006).

Flowcharts are essentially useful in capturing an overview of a business process up to a certain level of complexity. Their usefulness diminishes when the process being described is too complex to follow or understand visually. What would be useful would be to use flowcharts as a basis to visually show an overview of a business process and point out the key variables and structures governing the process (Tumay, 1996).

2.2.2 Integration Definition techniques (IDEF0, IDEF3) Overview

Integration Definition, abbreviated to IDEF, is a family of methods that find its use in process modelling (Aguilar-Saven, 2004). Most relevant to business process modelling are the IDEF0 and the IDEF3 methods, which will be discussed below.

The IDEF0 method is well known for its use in the facilitating the analysis of a process and the communication between the modeller and the stakeholders involved in the process. A graphic layout of the activities of the process and the inputs, outputs, mechanisms and controls governing the process assists the modeller in pinpointing the problem areas of the process and the strengths of the process (Webmaster, 2010).

The IDEF3 method focuses on modelling the behavioural features of a system. This process modelling technique takes into account the different perspectives of how things work within a system. This method is more focused on *how* the system works rather as opposed to the IDEF process which focuses on *what* activities the system performs (Webmaster, 2010). This allows for stakeholders to evaluate the model and express their thoughts around the process and discuss what it does or could do (Webmaster, 2010). The IDEF3 method has been known to be useful in Business Process Engineering, Business Process Reengineering (BPR), Software process definition and improvement and Software development and maintenance (Aguilar-Saven, 2004).

Given that one of the primary uses of the IDEF technique is communicating what goes on in a process, one of the cited problems of the IDEF technique is its decreasing usefulness in communicating a process when the process modelled is complex or when the description of the activities of a system is refined to a greater and greater detail. Beyond a certain level of description or complexity the model may become understandable only if the reader is a domain expert or has participated in the model development (Webmaster, 2010).

2.2.3 Basic Petri nets Overview

Petri nets technique makes use of graphics/diagrams to represent a system with the intention of facilitating the analysis of the structure and dynamic behaviour of the system as a whole, drawing particular attention to the interdependent relationship amongst the variables governing the system.

Figure 2.1 below shows a graphic representation of a Petri net modelling for a process where a consumer requests for a replenishment of goods where the process of shipping the goods and receipt of payment run concurrently, with the shipment of goods dependent on receipt of payment.

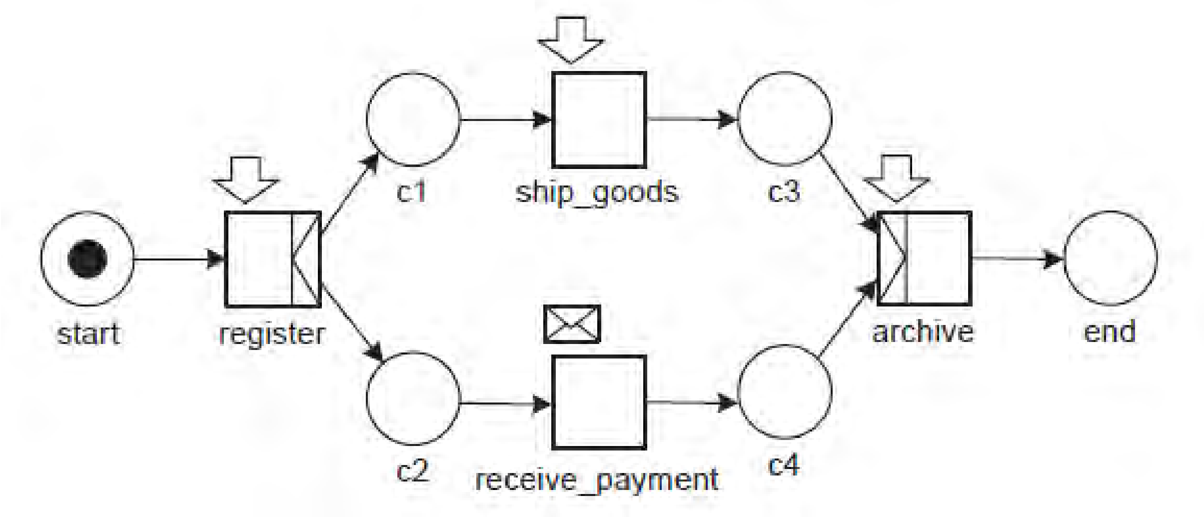


Figure 2.1: A superclass WF-net (van der Aalst, 1998)

Such graphical representation of a system makes it relatively easy for the reader of the model to get a sense of the different states of the process and interdependent relationship amongst the variables governing the system with different processes running concurrently throughout the system. The simple notation of using circles, rectangles and arrows facilitates the ease of understanding the system as a whole.

From a practical application point of view, the application of basic Petri nets originally has its drawbacks. The Petri net model has to be modified to allow for data entry and hence the model becomes excessively large, a problem that was dealt with later through the use of Coloured Petri-net (CPN). Aguilar-Saven (2004) and Giaglis (2001) both note the limitations of using Petri nets to model for high-level, complex business process. It becomes time consuming to do so, and the models become excessively large and not succinct.

2.2.4 Simulation – System Dynamics Overview

The role of simulation in business process modelling is to give the reader of the simulation model a chance to evaluate and better understand the process being modelled. This takes away the risk of implementing uninformed changes to the real-world system that may lead to unintended consequences that may prove to be costly (Giaglis, 2001). This makes SD a useful a useful approach in the modelling, evaluation and understanding of complex systems. The complex systems are governed by feedback loops, casual relationship between variables and dynamic structures that change over time that affect the system as a whole. SD analysis allows for the analysis of expected and unexpected results that are brought about by changes to variables within the complex process (Webmaster, 2014).

The model simulations of policy implementations and "what-if" scenarios assists stakeholders in clarifying which key variables and structures bring about certain expected and unexpected results. This has made the SD approach beneficial within areas that deal with dynamic problems arising in complex social, managerial, economic, or ecological systems.

Giaglis (2001) notes that SD is useful in studying the dynamic behaviour of a system but if this is of limited importance to the overall objective of modelling the business process then SD is not as useful. Giaglis (2001) points out another problem where the technique's limited range of primitive analytical constructs compels the analyst to adopt a specific (usually high-level) approach which can sometimes limit the scope of analysis achievable.

2.2.5 Knowledge-based techniques Overview

Knowledge based techniques, knowledge-based systems (KBS) being one of them, attempt to model a system that matches the reasoning power of experts. Such a technique is based on artificial intelligence (AI). A notable KBS was the MYCIN program developed in the 1970s. The MYCIN KBS made use of AI to recommended appropriate antimicrobial therapy to patients suffering from infectious diseases that required antimicrobial therapy. This system would advise physicians on the type of therapy required before complete information about the organism was available, allowing for patients to start the therapy in good time (Shortliffe, et al., 1975).

Within a business process context KBS is useful in performance evaluations, it is also useful as a predictive tool, as well as in facilitating decision-making. Ba *et al.* (1997) point out the following potential applications:

- Diagnosing the performance of a firm
- Predicting the behaviour of an organization over time
- Testing the implications of theories about organizations
- Supporting business reengineering
- Strategic business decision-making

The wealth of knowledge that assists the model in coming up with solutions to a specific problem is built from assumptions, general knowledge, qualitative knowledge, numerical models, varying perspectives around the matter at hand (Ba, et al., 1997).

It would seem as though there is a high cost involved in the building of a KBS. The time consumed and money spent gathering a knowledge base and incorporating it into a model may prove to be too costly for researchers to use this technique. In addition to this, many users outside of the modellers and experts may still not be willing to trust the solutions put forward by the system without seeking a second opinion from experts, which then defeats the purpose of having the system (Webmaster, 2014).

2.2.6 Role Activity Diagrams Overview

Role activity diagrams (RADs) are diagrammatic notations that model a process from the perspective of individual or group roles within a process, modelling for their activities and interactions with other roles (Giaglis, 2001).

The user-friendly notion of RAD makes it popular in process modelling. This notation allows for easy translation of a process into a diagram that can be communicated with relative ease. RADs provide a different perspective of the process and are particularly useful in supporting communication. They are easy and intuitive to read and understand presenting a detailed view of the process and permitting activities in parallel (Aguilar-Saven, 2004).

RAD have seen their use mainly in software design and organisational process modelling. Roles are abstract notations of behaviour describing a desired behaviour within the organisation. They are often organisational functions. They also include software systems, customers and suppliers (Aguilar-Saven, 2004).

It has been noted by Aguilar-Saven (2004) that one of the weakness of the RAD technique is its different notation compared to other conventional notations. Giaglis (2001) notes how RAD mostly complements other techniques in business process modelling, restricting their role to being mostly complementary in the context of business engineering.

2.2.7 Conclusions on Business Process Modelling

The business process modelling and simulation, incorporating features of SD are seen as adequate modelling approaches given our case study. We wish to study a business process that we believe has potentially complex dynamics between and amongst qualitative and quantitative variables. Given the objectives that look at various policy implementations and "what-if" scenario simulations, SD allows us to gain insights into key variables and structures that bring about certain expected and unexpected results from the simulations. Model simulations allow us to study the behaviour of the business process over time, allowing for us to understand the behavioural trends of the process given the objectives being addressed. The fact that the business is still relatively young, and data and information with regards to the business process is relatively limited, SD also allows modellers to make use of limited data and information, in conjunction with information provided from stakeholders, usually with expert insights into the process, to model for the process and make insights into the objectives. Studying a small firm that is relatively young also leads to uncertainties around the values of some input parameters and their behaviour over time. The simulation models then allow us to model for random variation about parameter values.

2.3 History of System Dynamics

The SD approach originates from the 1950s where it was developed to assist corporate managers in improving their "understanding of industrial processes…" (Forrester, 1997). Below we document the sequence of events behind the growth and development of SD, giving relevance to its application and usefulness in complex matters.

The origins of SD stems from the 1950s at MIT where it was used as a methodology for relating the structure of complex managerial system to their performance over time via use of simulation (Forrester, 1997). Forrester attempted to understand the fundamental issues that led to the success or failure of businesses. His first study began at General Electric (GE) where Forrester helped to uncover the "employment instability" the firm experienced. The firm could not understand the reason behind its high turnover of employees. The firm had ruled out the externalities such as the business cycle as a cause of the turnover. Forrester later discovered that the instability was actually due to factors within the firm, mainly the firm's corporate decision-making structure for hiring and firing workers.

In the 1960s SD played its role in social development, outside its corporate use, when Forrester aided John F. Collins (the mayor of Boston) in understanding the social and political dynamics of the city and the variables that govern them. For a year Collins arranged for a large number of people involved in politics and businesses in the city to meet each week for discussions centred on understanding the complex social and political systems of the city (Forrester, 1969). This gave birth to Forrester's Urban Dynamics which looked into the urban problems of the city overtime (such as employment problem, housing and the industry), the causes behind the problems and exploring plausible and possible long-term solutions to the problems given the dynamics of the city.

Again in the late 1960s it was used outside the corporate sector. One notable non-corporate application of SD was its use by the Club of Rome, which dedicated its resources to solve what the organisation members termed the "predicament of mankind". Forrester was at the forefront of formulating a SD model dubbed "WORLD1" that examined the problems behind the increased demand of non-renewable and renewable resources in light of the world's exponentially growing population, and issues behind ever increasing pollutant emissions (Forrester, 1971). Later, a more concrete WORLD2 model was formulated by Forrester.

This model outlined the dynamics behind, and feedback structures between, world population, industrial production, pollution, resources, and food. WORLD2 predicted a collapse of the world socioeconomic system within the 21st century if steps were not implemented to mitigate the demands on the earth's resources. The WORLD2 model also aided in pinpointing policy changes capable of sustaining world resources far into the future (Forrester, 1995).

The relevance and usefulness of the SD approach was highlighted recently in the 1970s when the approach was used to settle a court case between Ingalls Shipbuilding and the United States Navy. In the 1970s Ingalls Shipbuilding had one of the largest shipyards (with regards to size, capabilities, manpower and sales volume) and was given two tasks by the United States Navy. The first was to build assault ships and the second was to build destroyers. In order to fulfil this obligation Ingalls had to double its workforce. The program suffered huge setbacks with regards to time delays and costs as the US Navy repeatedly changed its designs. A SD model was formulated to investigate the dynamics that led to the incurred cost and schedule overrun for the two multibillion dollar projects (Cooper, 1980). Using the SD model, Ingalls was able to back a $500 million shipbuilder claim against the US Navy for cost incurred due to the Navy's delays and design changes. A $447 million out of court pay was made by the Navy to Ingalls. The success of the model has led to Ingalls using SD in aiding strategic decision making in managing its shipyard operations (Cooper, 1980).

2.4 Two Pertinent Case Studies Employing System Dynamics

2.4.1 A System Pathology of an Organisation: The Rise and Fall of the Old Saturday Evening Post (Hall, 1976)

The case study draws heavily from the journal article by the same title by Hall (1976). The Saturday Evening Post is a magazine published in America on a bimonthly basis. Its first issue was published in the late 1800s and flourished before its gradual decline from the mid-1900s, leading to its eventual demise in 1969. The SD technique is the basis used to model and evaluate the rise and fall of the old Saturday Evening Post, as the author of the publication delves into understanding the reasons behind the demise of the paper.

At the Saturday Evening Post numerous internal and external factors played a role within the process during its tenure. These factors included rise in TV viewership, the rise in print and postal cost, circulating revenue (i.e. revenue from people buying the magazine) and advertising revenue. The variables formed part of a complex process with dynamic structures that impacted both the rise and fall of the company.

In the context of the magazine company, management had control over annual subscription rates and advertising rates. Management's decisions as to how much to charge for these were largely determined by how the company was performing. The strength of the model is validated by the fact that the writer had 20 years of data available to him with regards to the magazine publishing company and industry. Assumptions made about the dynamic structure of the model could readily be validated by data at hand.

A few key findings are taken from this article. Important to our research is how we see the SD technique being used to outline the complex dynamic structures governing a process, and how the technique is used as a centre point to hold discussions in order to get a better understanding of the system, providing a more detailed analysis (compared to mental modelling) as to what caused the fall of the magazine. Crucial to our research is the way in which the SD approach, through the use of Dynamo programming software, enabled the author to delve into "what-if" scenarios, and evaluate what management decisions and policies could have been adopted to prevent the fall of the magazine. We also see how, through the use of sound data (data from over a period of 20 years), the author was able to validate assumptions made in the building of the model; producing a useful model that aided in understanding the dynamics behind the fall of the company. What we draw from this is how the SD approach was useful in giving insight into some of the key variables and dynamics governing the success and failure of the company. This gave the author an understanding of how certain policy implementations may affect the process as a whole.

Of interest is the author's recognition that processes may be better modelled if management decision making processes were incorporated in the model. In our case study we intend to accomplish this through cognitive mapping sessions with the firm's management with the hope of getting a better understanding of the thought processes governing management decisions with regard to the firm's past, present and future growth path.

In a similar way to the case study, we wish to evaluate the impact of different policy implementations on the firm's business process. But unlike this case study, our analysis is largely based on "what-if" analysis and makes use of far less concrete data. The strength of our model is mainly reliant on stakeholders' understanding of the complex dynamics, feedback structures and inter-relationships governing the process. The modelling technique we use also takes on a much softer approach where we model qualitative aspects such as morale and health that impact the process.

2.4.2 Modelling a Biotechnology Start-up Firm (Morecroft, et al., 1989)

Before we talk about the relevance of cognitive mapping in our case study, we must first take a look at the importance of interaction with stakeholders in our model building process. The importance of discussing models with stakeholders and building in the feedback obtained from these stakeholders is outlined by Morecroft *et al.* (1989) in his SD approach in *Modelling a Biotechnology Startup Firm*. Here he outlines how the SD approach provides a platform for discussion with regards to policy implementations a firm may be considering. As stakeholders meet to build the models, it becomes more apparent to everyone involved what the key variables, dynamic feedback structures and inter-relationships are, as different viewpoints with regards to how the process runs are brought to the front.

In this particular instance SD is used to open up a forum for discussion surrounding growth management at the firm. Operational process and distributional process are modelled, providing the stakeholders involved with a centre point of discussion. The model building process is structured in such a way that the stakeholders involved are not lost in the complexity of SD terminology, "much time and effort was spent on choosing model concepts and vocabulary suited to the business and to thinking carefully about units of measure and dimensions" (Morecroft, et al., 1989). For them, it was very important to keep the models presented to management simple enough to understand and run. The intention was to keep people interested in discussing ideas and come up with various policy implementations that would bring about growth of the firm.

The stakeholders involved therefore came together to build a sound model given available data, with the model incorporating various viewpoints. Then using a validated model, people began to evaluate different policy implementations with regards to the above capacity allocation, customer recruitment and market growth. Through ongoing simulation runs and trying out different scenarios and discussing the results obtained, the stakeholders involved were able to get a better understanding about the consequences of their policy implementations. In a similar way, we shall make use of expert opinion from management and stakeholders involved in the process under study. However, our approach and objectives shall be academically aligned to our topic of exploring the business processes using a SD approach to get a better understanding of their structures and investigate their response to various policy implementations. Our main focus is not on answering objectives set out by management or to use SD as a predictive tool.

2.5 Modelling Qualitative Variables

In this section we review how qualitative variables have been modelled into processes. We make sure to take note of the concerns around incorrectly or inadequately modelling for qualitative variables. Jay Forrester does acknowledge the importance of qualitative variables in modelling processes.

"To omit such [soft] variables is equivalent to saying that they have zero effect – probably the only value that is known to be wrong!" (Forrester, 1969)

2.5.1 System dynamics applied to project management: a survey, assessment, and directions for future research (Lyneis & Ford, 2007)

This section draws heavily from the journal article by the same title by Lyneis & Ford (2007). The journal article reviews structures underlying project dynamics, including structures governed by qualitative variables. The structures described by the authors share similarities with those that make up a business process, therefore making this paper useful in our research.

The structures within a dynamic project are typically made up of causal, interdependent nonlinear relationships that lead to the dynamic behaviour of a project. This type of structure has made the application of SD to project management a fertile and productive field of study. Lyneis & Ford take a look at four model structure groups that typically govern a project, relating the structures to the SD approach. We review the some of the model structures, giving a more detailed overview of the structure related to qualitative variables (Ripple and knock-on effects).

The common feature of all SD project models start with a stock of tasks that need to be completed. The next stage is the flow of the stocks through a development process, which the ends with a stock of complete tasks resulting eventually in the completion of the project. The SD approach allows for the modelling of resources that facilitate in the development process with project managers typically deciding on the allocation of resources.

When using the SD approach to model for project management the modeller typically allows for the possibility of rework and the potential problems that rework may bring about within a process. This gives management an idea of the delays and problems they may face if a relatively large amount of rework needs to be done. Depending on the insights from the model runs they may push for an intensive quality control stage within the project process so as to mitigate delays and problems that come with rework.

Typically with process management of projects, project managers usually put in place measures to control the performance and progress of a project. One example of controlling feedbacks is the use of overtime to meet deadlines. Other actions that are taken by management to control the performance and progress of a project include increasing workforce capacity and/or increase work rate. A further example of controlling measures is when project managers revise deadline dates to a later date. The consequences of these impose costs (monetary and other types).

Ripple effects

Here we review some policy implementations that project managers put in place to facilitate project performance that may lead to unintended negative consequences due to dynamic structures with the project that they may not have perceived or accounted for. Lyneis & Ford (2007) note how actions taken to close a gap between project performance and targets have unintended side effects (ripple effects) that generate policy resistance. These ripple effects are the primary impacts of project control on rework and productivity. For example, hiring people in order to increase productivity may actually dilute experience as workers with less skill and/or less familiarity with the project are brought on. In addition, hiring these individuals means that experienced individuals have to take time out of their work to train them, which adversely affects productivity. On the other hand, resorting to overtime may lead to fatigue over time. Fatigue may then lead to an increase in errors and decreases productivity.

Knock-on effects

The knock-on effects are typically the harmful consequences that cause problems to other areas within the project process.

Haste creates out-of-sequence work. The consequence of trying to accomplish more tasks, typically in projects with a number of parallel processes, may see some process completing tasks ahead of schedule and still having to wait for other process to complete their tasks to move forward creating out-of-sequence work.

Errors build errors. Undiscovered errors that are discovered towards the end of the development process means that this work has to be sent back to the initial stages of the development process. The added work results in increased work pressure due to more work having to be done in this phase, leading to a further increase in errors. Another consequence of this could be *an* increase in work required because fixing the errors takes more effort than doing the original work.

Hopelessness. A result of fatigue and rework is a sense of "hopelessness" as level of fatigue and rework continuously increase. This may see an increase in errors, reducing productivity, and could result in turnover of employees.

Accounting for ripple effects and knock-on reinforcing effects in SD modelling gives managers insights into the consequences, most importantly unintended consequences, they may face should they implement certain policies that they believe will facilitate project performance and progress. This is especially helpful to managers should they find that the relationships governing the project processes include nonlinear relationships and through model simulations they are given a scope as to how controllable the variables governing the behaviour of a project are.

In our case study, we wish to highlight some of the unintended consequences that are brought about by policy implementations within the firm's business process. We wish to gain insight into some of the ripple effects and knock on effects that bring about these unintended consequences. Through the analysis of these effects we intend on getting a better understating of the firm's business process and how it affected by different policy implementations and "what-if" scenarios.

2.5.2 A generic model of project management with Vensim (Li, 2008)

As we mentioned earlier, Li (2008) uses the SD approach to highlight how useful the approach is in improving project management, more specifically highlighting how it can be used to explain project failures by making use of a generic model. The basis of this generic model is built on work done by Lyneis & Ford (2007) in the article we just discussed above.

Below we review how Li (2008) incorporated and modelled for qualitative variables in her generic model in her paper "A generic model of project management with Vensim". We review the interdependent, cause and effect relationships between qualitative variables, as well as quantitative variable, observing how the qualitative variables go on to impact productivity.

In Li's paper, and relevant to our research, the author documents the impact of fatigue and morale on project progress and performance, variables that we consider to be qualitative. With regards to fatigue, she illustrates the impact that overtime has on fatigue and how this then leads to error generation resulting in a decrease in productivity through what she calls *Multiplier to ErrGen due to Fatigue*, equated as follows:

Multiplier to ErrGen due to Fatigue = WITH LOOKUP (Exhaustion Level,

([(0,1)-(100,2)],(0,1),(10,1.02),(20,1.07),(30,1.17),(40,1.21), (50,1.23),(100,1.23))),

whereby an increase in exhaustion levels from 0 to 100 results in an increase in the multiplier effect.

She goes on to link morale levels to fatigue levels and schedule pressure, documenting how increasing levels of fatigue as well as increasing levels of schedule pressure leads to a decrease in morale through what she calls *Multiplier to Morale due to Fatigue* and *Multiplier to Morale due to Schedule Pressure* respectively. Figure 2.2 illustrates the modelling of Multiplier to Morale due to Fatigue and Multiplier to Morale due to Schedule Pressure.

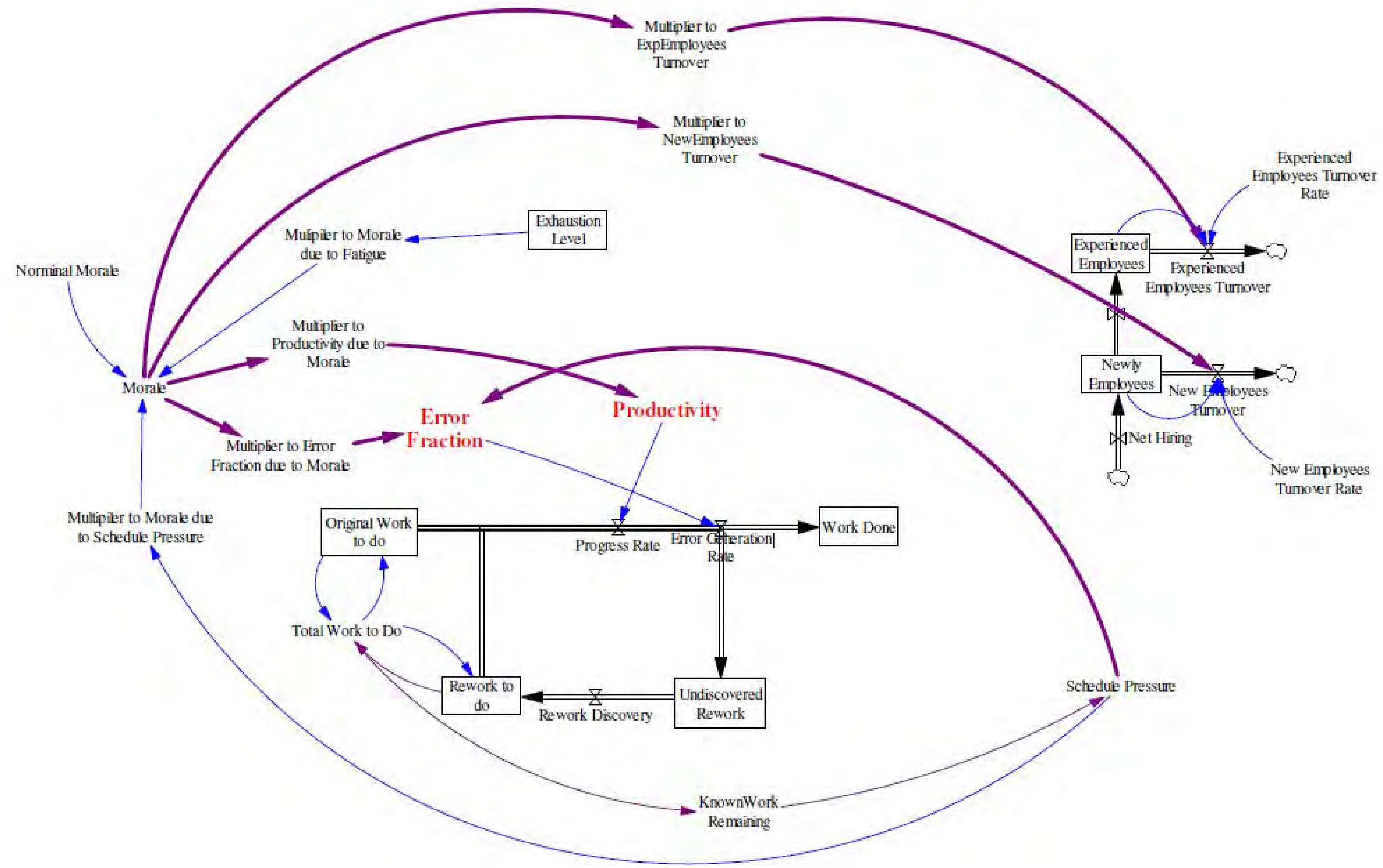


Figure 2.2: Hopelessness (Li, 2008)

In a similar way, but making use of our own data and information, we wish to incorporate qualitative variables within our model. Li's modelling of qualitative variables mainly looks into how they affect error generation. Our model, given the information provided, sees qualitative variables directly and indirectly affecting productivity through interactions with other qualitative variables, quantitative variables and structures within the business process. Li takes a generic approach to the model a generic project, using general parameters. We, however, intend to model for a specific business process using parameters as drawn from data and information provided by RWers involved in the process and expert opinion from the firm's management team.

2.5.3 Organizational Culture and Performance: Proposing and Testing a Model (Marcoulides & Heck, 1993)

In the journal article titled, "Organizational Culture and Performance: Proposing and Testing a Model" (Marcoulides & Heck, 1993), we take a look at the method used by the authors to collect information with regards to organizational culture and performance, variables that are considered to be qualitative in nature. Apart from the method used, we take a look at the strengths, as well as limitations, of modelling for their qualitative variables as noted by the authors.

The authors in this paper describe how the culture of an organization affects the performance of an organization. To test their hypothesis they gathered data around organizational performance and organizational culture from a sample of 392 respondents. Analysis of the data from this sample confirmed the fit of the proposed model to the data. Adequately modelling for key variables, relationships and dynamic structures that define organizational culture and its effect on organizational performance gives individuals and understanding about the links between the organizational culture and performance. It also gives individuals an insight into the different policies that may sustain or improve organizational performance through organizational culture. We now focus on their methodology in collecting data on organizational culture, a heavily qualitative construct.

Method

Data and information was collected from a sample set of Three hundred ninety-two (392) participants randomly selected from 26 organizations that were randomly selected from two geographic regions from the midwestern and western parts of the United States. The sample of organizations varied in product/ service offering, size (capital intensive or labour intensive), ownership (public or private), and objective (for profit or not-for-profit).

The study involved the participant going through a structured interview followed up by a questionnaire. The interview and questionnaire were developed based on a framework adapted from Hackman and Oldham (1976). The interview and questionnaire focused on questions around underlying variables perceived to influence the culture of an organization. For example, participants were asked: "Please indicate the extent to which supervisors and subordinates tend to work cooperatively in your organization." Using the five-point Likert-type scales with responses ranging from "strongly agree" to "strongly disagree." Past data on indicators of organizational productivity were also collected from organizational records. The participants, on average, had an hour interview and half an hour to complete the questionnaire.

From here, a preliminary roster of the latent variables underlying organizational culture was drafted. The list was drafted based on constructs considered in the literature to be predictive of organizational performance. Several preliminary models of the interrelationships between the observed variables and the hypothesized constructs of organizational culture were developed and tested via confirmatory factor analysis before a final model was proposed. From this, the hypothesis was that organizational culture is composed of five interrelated latent variables as follows:

- Organizational structure/purpose (OS) - This construct reflects the structure and operational processes of an organization.
- Organizational values (OV) - This construct or latent variable (the terms can be used interchangeably) describes the principles, ideologies, and values that an organization holds as desirable in the practice of serving its clients.
- Organizational climate (OC) - This construct is described by the perceptions of workers about a variety of conditions concerning the work environment.

- Task organization (TO) - This construct represents the typical strategies, policies, and actions used by the organization in achieving its production goals.
- Worker attitudes/goals (AT) - This construct reflects the beliefs of employees about a variety of issues related to social, political and organizational concerns, some of which may be influenced by the organization and some of which may be separately determined.

Each of these variables is measured by various underlying variables. For example, worker attitude is measured by the extent that employees resent recent organizational policies in acceptance of minorities (Prejudice/Tolerance), regard nationalism as important (Nationalism), regard common courtesy and punctuality as important work attributes (Social Amenities), regard dedication and commitment to the organization as important (Commitment), and the extent to which employees perceive that management involves them in the decision-making process (Involvement).

Overall the paper lays out how the culture of an organization can be measured after defining variables that govern organizational culture, taking into account their key variables, relationships and dynamic structures. These variables then are used to explain the effect of organizational culture on organizational performance. From here, individuals can get an insight into the different policies that may sustain or improve organizational performance through organizational culture. The authors do warn of the possibility of modellers to omit key variables or relationships, or even measure them inaccurately. For example, an individual's verbal report measure of perceived pressure on the job may, or may not, adequately capture a key idea of organizational climate in the model. And even if it does, the way the individual's reply is coded into a score may destroy its meaningfulness.

2.5.4 Quantifying the Soft Issues: A Case Study in the Banking Industry (Akkermans, 1995)

We review the journal article titled, "Quantifying the Soft Issues: A Case Study in the Banking Industry" (Akkermans, 1995). The author of this article reviews a case study where the quantification of qualitative variables was necessary in the development of a decision-support system to assess the costs and benefits of closing down underutilised bank branches.

Managers were not only concerned with the financial costs and benefits of such a move, but also how customers would react to bank closures. Techniques were used to capture and quantify soft variables, for example, "level of expected customer irritation". The paper allows us to see how modellers quantified qualitative variables for the purpose of developing a decision-support system.

The modellers of the decision support system needed techniques to capture and incorporate soft variables into their decision support system. Three main steps were taken to quantify soft variables:

1. *Mapping soft issues in casual diagrams*

From various interviews and group session, assuming with customers, internal experts in the content manner at hand and two local bank managers, a causal diagram was constructed that captured the possible cause-effect relationships that would result from bank closures as customers now had to look for the next nearest bank branch (Figure 2.3 below).

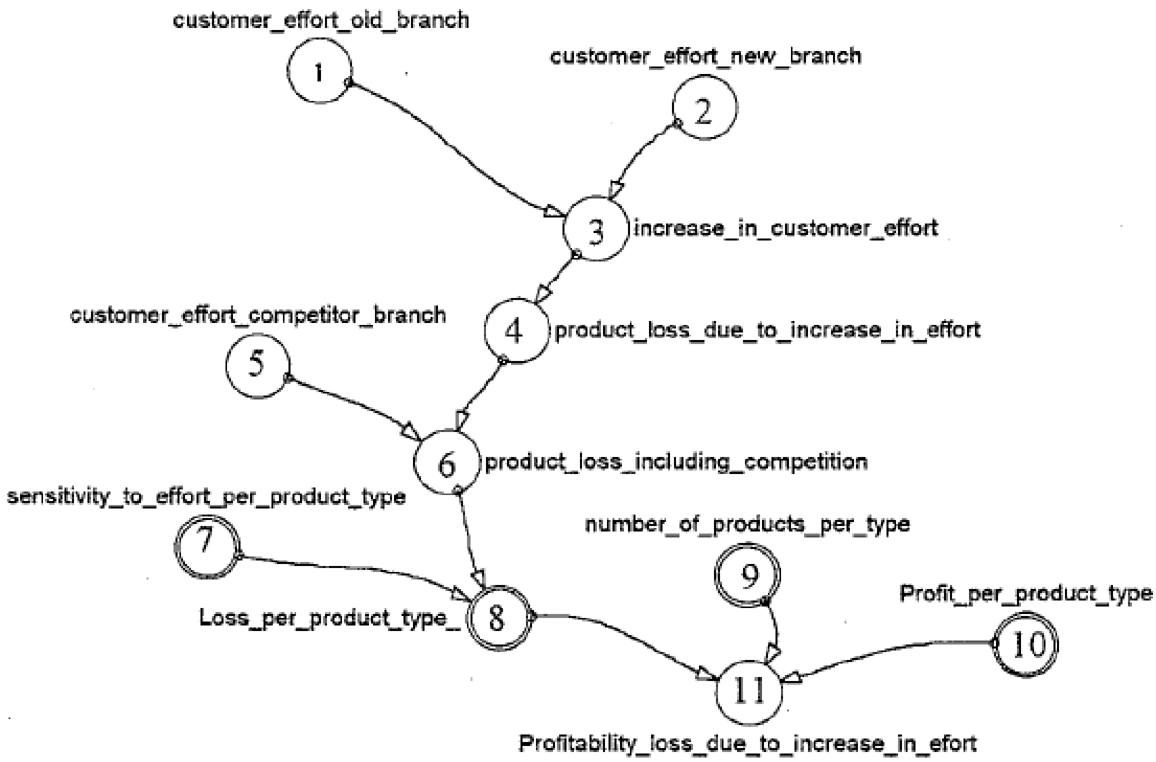


Figure 2.3: Causal diagram showing effects on profitability of increased customer effort after closure (Akkermans, 1995)

This diagram can be read as follows: the bigger the difference (3) between the effort required to reach the old (1) and the new branch office (2) (increase_in_customer_effort), the higher the losses of products – such as savings accounts, or insurances – due to increased customer effort (4). The better the accessibility of the nearest branch office of a competitor (5: customer_effort_competitor_branch, the higher these losses will be (6). Not every product type is equally as sensitive to such a decrease in accessibility (7). For instance, very few people will cancel their mortgage loan because their local branch office is closed down, but many parents will switch their savings account of their children if these have to walk a long way to the bank. In this sense losses per product type can be determined (8), which can be multiplied by the number of each product type sold in this area (9) and the profitability per product type (10). In this way, an estimate of overall profitability loss due to increases effort can be obtained (10) (Akkermans, 1995).

2. *Converting soft relations into scales*

Initially a causal diagram was drawn up that incorporated numerous variables such as:

- The location within a shopping centre
- The quality of the shops nearby, the availability of parking space
- The proximity of a large road
- Age and wealth distribution of the local population

Over time, the variables were then scaled down to a smaller number measured using a five-point scale; variables that would then affect some of the variables in Figure 2.3. These scales were constructed via group sessions and workshops, with bank experts jointly agreeing on adequate formulation of each subsequent level. The following shows the five-point scale developed for customer irritation that would affect branch accessibility (i.e. variables 1, 2 and 5 from Figure 2.3).

1. *Minimal irritation*: No reaction on closure. Atmosphere of silent agreement.
2. *Modest irritation:* Customer irritation is voiced by clients complaining at the counter. Verbal reactions, which do not result in actions
3. *Normal irritation:* Considerable number of verbal complaints from customers. Some local bank managers are approached individually by customers.

4. *High irritation:* Great number of individual complaints, voiced also in local newspapers. Local shareholders start asking questions at local board meetings. This level result in actions, in the preceding three irritations remained verbal.
5. *Very high irritation:* The main difference with high irritation is that here organised group actions take place. A great deal of publicity, organised opposition in board meetings and other political activities.

3. *Developing graphical functions*

Graphical functions are then created for the relations between variables. The functions were developed in the group modelling workshops with six experts after coming to an agreement for each function. The example illustrated below in Figure 2.4 looks at the graphical function between customer irritation (X-axis) and % lost sales of service type 1, service type 1 being deposits or debts.

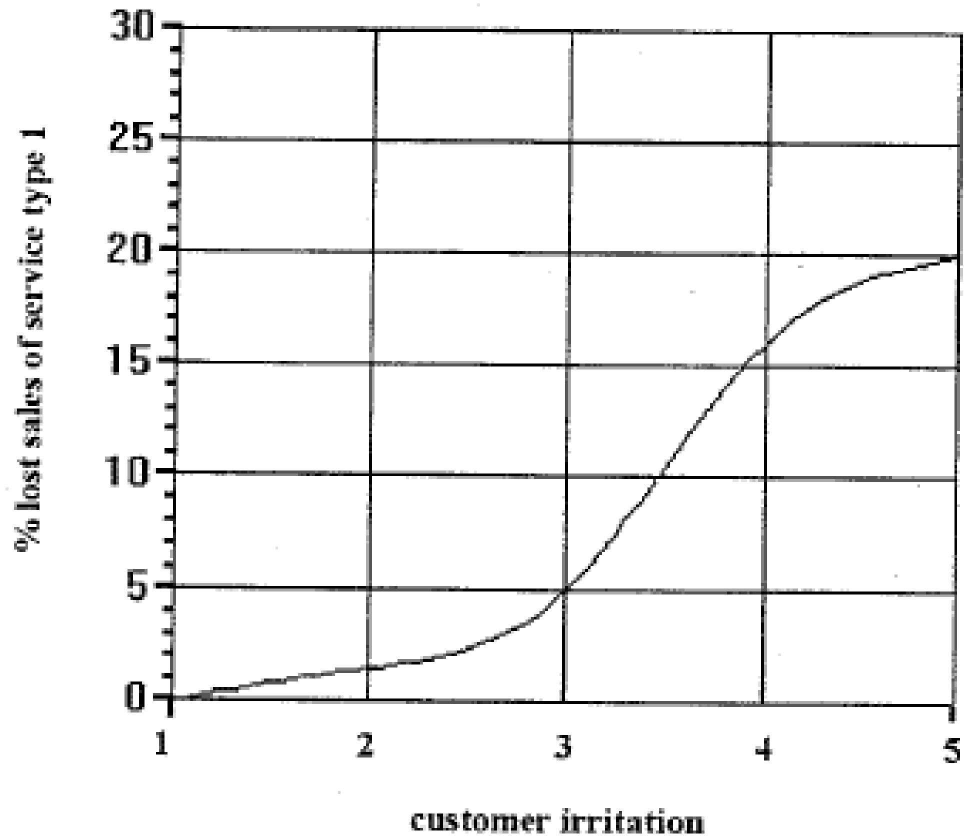


Figure 2.4: A graphical function for the "soft" relation of the effect of customer irritation on profitability (Akkermans, 1995)

The development of the function starts with assigning ranges to the independent (X-axis) and dependent variable (Y-axis). Given a value of X, one assigns a value to Y. The author notes that for situations where if it is hard to denote a single value, one can draw a hi-low bar to indicate the plausible range of Y values. The next step involves assigning Y values to X=0 and X=maximal. One repeats this procedure for various intermediate points. At this point it is useful to consider whether there is any reason to suppose the relationship would have a particular general shape. Is it linear or non-linear? In this case, an S-curve was judged as most plausible at low levels of irritation, minimal losses will occur; then there is a level of irritation at which most of the "defections" to competitors will take place But in the end, most customers will not go so far as to actually take their deposits or debts away from the bank, regardless of how irritated they get (because doing so costs them money, of course). From there, one then attempts to draw a line through more or less the mid points of the scatter bars of Y values that have been assigned to various levels of X. This becomes the graphical function.

From a qualitative modelling point of view, the project was said to be a success as participants who were part of case evaluation showed a confidence in the quality of the model. The author does notes the amount of time invested in quantifying qualitative variables and strongly recommends that if the conceptual modelling of the problem gives adequate answers to the problem at hand then there is no purpose to modelling the problem further. Furthermore, the author notes that there should not be a need to model in soft variables if the client is not concerned with these. However, if the modeller or consultant feels that the client may be miss out on key insights by leaving out these, or any other variables, the modeller or consultant should attempt to get the client into the model formalisation stage, however difficult that may be.

2.5.5 Incorporating Soft Variables into System Dynamics Models: A Suggested Method and Basis for Ongoing Research (McLucas, 2003)

Another article on the quantification of soft variables is written by McLucas (2003) titled "Incorporating Soft Variables into System Dynamics Models: A Suggested Method and Basis for Ongoing Research". In this article the author discusses the difficulty of quantifying soft variables and determining the size of the impact they have on system.

The author also puts forward a method for quantifying and incorporating soft variables. This method is very similar to the one by Akkermans (1995), which we have previously discussed. We take a look at the concerns around modelling for soft variables, and the other considerations that Akkermans (1995) did not explicitly consider but McLucas (2003) takes into account more explicitly.

The problem lies in making sure that the incorporation of soft variables produces meaningful, reliable and repeatable results. The main point that the author draws to readers is that methods that are not sound that are used to incorporate and quantify soft variables are likely to corrupt the model and its dynamics, leading to wrong results and insights being drawn, resulting in fallacious learning experiences for the parties involved.

Coyle (2000) also gives examples of where the modelling of qualitative variables has been done so questionably, destroying the credibility of the insights drawn from the models. He does however note usefulness of incorporating important qualitative variables within a model, should the need arise, but argues that to quantify the variables in an unreasonable way is reckless (Coyle, 2000).

The author then raises some good points with regards to the importance of soft variables in system dynamic modelling. Similar to Akkermans (1995), he notes that in cases where soft variables are important to the purpose, they should be incorporated into the model. Omitting soft variables you know to be important because one cannot quantify them will likely result in biased insights and results. He notes the importance of insuring that the proper statistical methods are used to quantify the soft variables, methods that are later comparable to numerical data once available. Of importance is the need for ways to be found to measure and quantify soft variables considered to be important in a sound way. If we cannot measure them, we should estimate them as best we can by methods that give consistent, repeatable and reliable results. If individuals were to do it any other way this could seriously damage confidence in the SD modelling discipline or, even worse, destroy its credibility as a modelling technique.

The method put forward by McLucas (2003) with regards to quantifying soft variables is very similar to the technique used by Akkermans (1995) where experienced or expert personnel are used to estimate cause and effect relationships in the absence of data. Figure 2.5 shows the method of graphing experienced or expert personal give an estimate for the level of influence $\delta_{a,b}$ (n) that A would have on B.

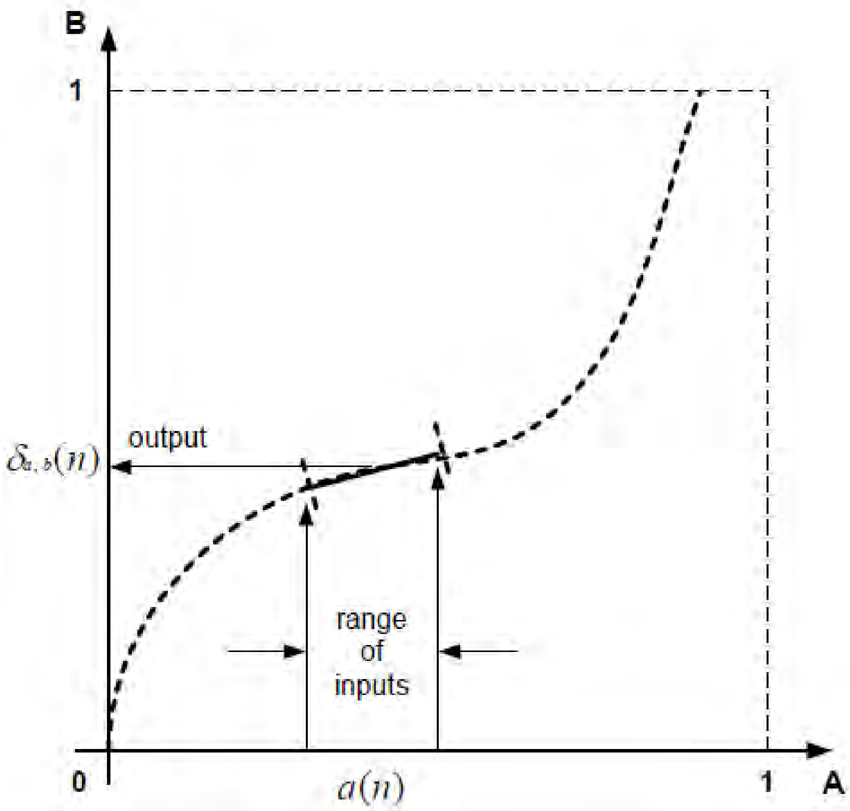


Figure 2.5: Causal Relationship between Node A and Node B (McLucas, 2003)

Of consideration, and not explicitly put forward by Akkermans (1995), is the need to assign a weighting to the level if influence that A has on B in relation to other variables that may affect B. In Figure 2.6 below, we see that variable B is influenced by other variables, A, G, N, U and Y. The author notes that to ensure the totality of influences at any node never exceeds 1.0, it is necessary to set to unity the sum of weightings applied to links influencing each node. At 'B' this would be expressed as:

$$w_{a,b} + w_{g,b} + w_{n,b} + w_{u,b} + w_{v,b} = 1.0$$

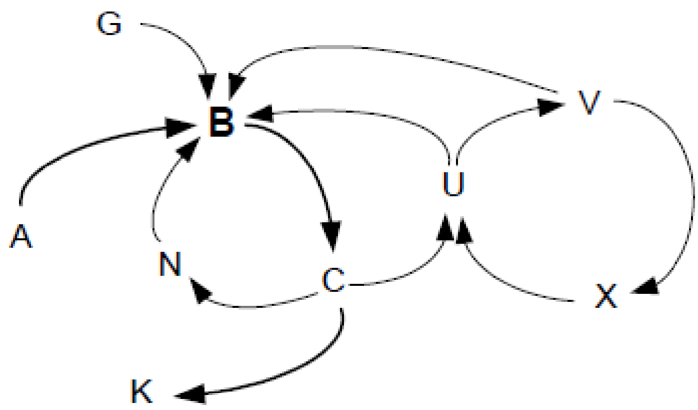


Figure 2.6: Generic Causal Structure

The author concludes his paper by emphasising the importance of developing methods of quantifying soft variables that give consistent, repeatable and reliable results. As noted by the author, avoidance of this ultimately translates to lack of skill and lack of consistency in the practice of our art.

2.6 Cognitive Mapping

Cognitive mapping forms part of our methodology with regards to setting out the objectives and building models that incorporate management's perspective of the firm's process. Eden (2004) in "Analysing cognitive maps to help structure issues or problems" outlines how cognitive maps might be analyzed for the purpose of structuring problems or issues. Insights from this paper are used to guide us in using cognitive mapping to obtain and incorporate management's perspectives in our models (Eden, 2004).

2.6.1 Analysing cognitive maps to help structure issues or problems

Eden (2004) discusses the use of cognitive maps in structuring problems or issues. The paper further outlines how cognitive mapping is a useful tool in the operational research sphere when it comes to problem solving. Eden (2004) begins by describing cognitive mapping as the "task of mapping a person's thinking about a problem or issue." He goes on describe a cognitive map as "the representation of thinking about a problem that follows from the process of mapping."

From an business process operational point of view, through the use of cognitive mapping, the modeller is able to get an idea of how management make sense of the business' process, detailing how management believe the process has developed over time and why it has developed in that way. The cognitive mapping can go further by looking into how management believe the process will develop over time into the future and why they believe it will develop in that way. This information is gathered through interviews with management. Eden (2004) sees this as obtaining an understanding of how humans "make sense of" their world by seeking to manage and control it.

Ultimately, the cognitive map assists the modeller of the process in incorporating structures or variables in the model that may not have been apparent had it not been for the cognitive map. However, the accurate incorporation of the structures and variables is very much dependent on the quality of the cognitive map. The quality of the map in turn is dependent on the quality of the interviewer as a listener and interpreter. As Eden points out "Maps are not just a graphical description of what is said, rather they are interpretations of what is meant by the interviewer." The amount of useful information about a process that could potentially be revealed through cognitive mapping, for example the discovery of loops within a process, makes its very useful tool in simulation modelling.

For our research, we wish to use cognitive mapping to incorporate management's strategic view of the business, and aspirations and goals into the models. The maps also give us a better understanding of how the business processes has been operating and is intended to operate in the future.

2.6.2 Using Cognitive Mapping to Develop a Large Forensic System Dynamics Model (Ackermann, et al., 1994)

We now review a case study where cognitive mapping techniques are used in SD modelling in relation to a case involving the management of a large development project that suffered disruptions and delays (Ackermann, et al., 1994). The article titled, "Using Cognitive Mapping to Develop a Large Forensic System Dynamics Model" draws lessons from the case study on the process of moving from a cognitive map to a SD model.

The model in this paper served as a mean to quantify the impact of delay and disruptions on a Mega Project for the purposes of a legal team representing clients of the project firm. The SD modelling approach served as transparent approach that could easily be audited by external analysts and provide a strong legal argument given its previous success in the dispute resolution with regards to the Halter Marine's (shipbuilders) 1981 lawsuit (Weil & Etherton, 1990).

The cognitive mapping technique was used to document and capture the different views and perceptions of the client team in terms of their view on the disruption and delay claim made. This was done through a round of interviews with key members of the client team. From this pool of information the team and its lawyer was able to learn more about the problem at hand and get a better understating of it. Furthermore, the cognitive mapping technique gave the team more information with regards key variables and relationships that gave rise to the delays and disruptions. Through this process, the lawyers were also able to learn about the structure of the model and problem and provide their input in terms of the legal validity of the model.

Using information gathered in the cognitive mapping stage and the influence diagram, a SD model could be built. From the whole exercise the authors note the richness in mixing methods that may be used to produce better models, and reach more insightful conclusions compared to individual techniques. By using a 'mixed methods' approach in a decision making process, different techniques can be applied at the points where they are most appropriate. The results produced by the different methods can inform and enrich one another, providing better models than the individual techniques could elicit on their own. Models generated in this way are also subjected to a greater degree of validation - each model provides a check on the others.

2.7 Summary

This literature review chapter reviews the different business process modelling techniques, citing their strength and weakness. The review of business process modelling led us to conclude that the SD is a suitable business process modelling technique given the business process we intend to model.

The technique was seen as suitable given the fact that the business process of the firm we intend to evaluate is embedded with complex dynamic relationships, mainly between qualitative variables and the rest of the system. The SD approach was seen as the most suitable in terms of assessing the consequences of policies made that affect the process, of which the consequences may be unintended or undesirable. A lack of data with regard to the firm's business process was also seen as a reason to use the SD approach, which facilitates the modelling of business processes with limited data.

We traced the history of SD and its use in various case studies as we saw in the case study of "A System Pathology of an Organisation: The Rise and Fall of the Old Saturday Evening Post" (Hall, 1976) and in "Modelling a Biotechnology Start-up Firm" (Morecroft, et al., 1989). The case studies highlighted how useful SD can be in uncovering the reasons behind unintended consequences brought about by policy changes to a system, and also the strength of the SD approach in the case where there is limited data as expert opinions and workshops are used to build the models.

We then reviewed modelling qualitative variables in the context of processes. We reviewed how it has been done in previous cases when we reviews "A generic model of project management with Vensim" (Li, 2008) and in "System dynamics applied to project management: a survey, assessment and directions for future research" (Lyneis & Ford, 2007). The models in these papers revealed the impact that qualitative variables have on productivity through various feedback structures and loops. We then went on to review the methods previously used to model for qualitative variables, highlighting the dangers of modelling for them in "Quantifying the Soft Issues: A Case Study in the Banking Industry" (Akkermans, 1995) and "Incorporating Soft Variables into System Dynamics Models: A Suggested Method and Basis for Ongoing Research" (McLucas, 2003).

The next section reviewed the cognitive mapping technique as a useful tool in gathering information and insights (Eden, 2004). We further reviewed how the cognitive maps constructed can be incorporated into SD models in "Using Cognitive Mapping to Develop a Large Forensic System Dynamics Model" (Ackermann, et al., 1994).

In summation, it was important for us to establish the SD approach as an adequate approach for our case study and highlight the importance of adequately incorporating qualitative variables into the model. We also established how cognitive mapping complements the SD approach, providing useful insights and information that assists in the model building. We wish to make use of the SD approach, to model, evaluate and understand what we perceive to be a complex business process governed by quantitative and qualitative variables. We believe that certain qualitative variables could have a significant impact on the firm's business process and as such there is a need for us to adequately model them. The cognitive mapping sessions with the management team provides us with insights into the business process. Insights from the sessions assist in building an adequate model that allows for the simulation of different policies and "what-if" scenarios, giving us insights into each of our set objectives.

3. The General Model

This chapter reviews the model building stages of the general model that we shall use to tackle our set objectives. The first section goes through a general overview of the model, which has been broken down into three main sections namely quantitative modelling, qualitative modelling, and workshops and cognitive mapping. Following the overviews, we take an in-depth look at each of these sections.

The general model is the base model used to build models for each objective mentioned in the introduction. The building of the general model starts with building few simple models. Eventually, as we got a better understating of the business process and gathered more data and information through workshops and cognitive mapping, the model grew into what we perceive to be a complex dynamic model governed by numerous equations and relationships (Morecroft, et al., 1989).

3.1 General Model Overview

In its simplest form the firm's business process can be graphically displayed as below in Figure 3.1. The tasking phase represents the inflow of work that comes in from the firm's various clients requesting actuarial reports within a given period of time. Junior Report Writers (JRWDFTers) then draft the actuarial reports. Senior Report Writers (SRWCHKers) then check the drafts and make changes to the draft if necessary before sending off the actuarial reports to the clients.

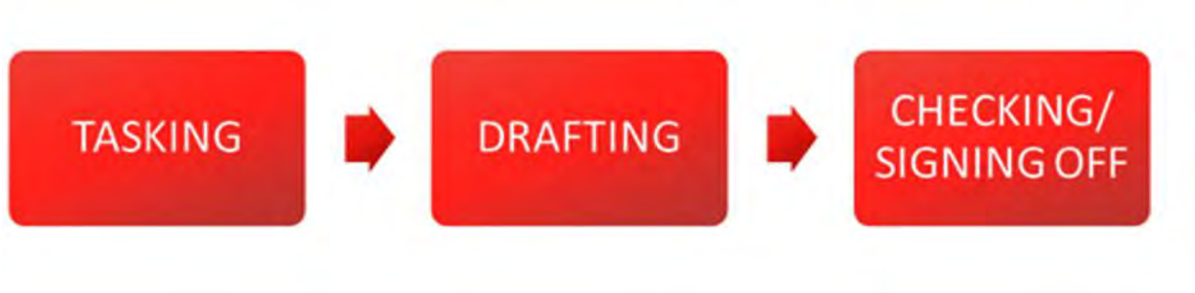


Figure 3.1: The firm's business process in its simplest form

Behind the tasking phase is the firm task rate which predominantly increases over time. The drafting phase sees JRWDFTers trying to match the task rate given a certain number of JRWDFTers and their skills set with their productivity negatively and positively affected by qualitative variables (health, morale and stress). The SRWCHKers make up the checking/signing off phase, with their productivity also dependent on their skills set and levels of their qualitative variables.

3.1.1 Quantitative Modelling Overview

In this section we overview the firm task rate, draft rate and check rate.

The firm task rate, draft rate and check rate is illustrated below (Figure 3.2) for a scenario with ten (10) JRWDFTers and five (5) SRWCHKers. Our period of analysis is 7 years, with 264 working days in a year, which works out to be 22 working days per month.

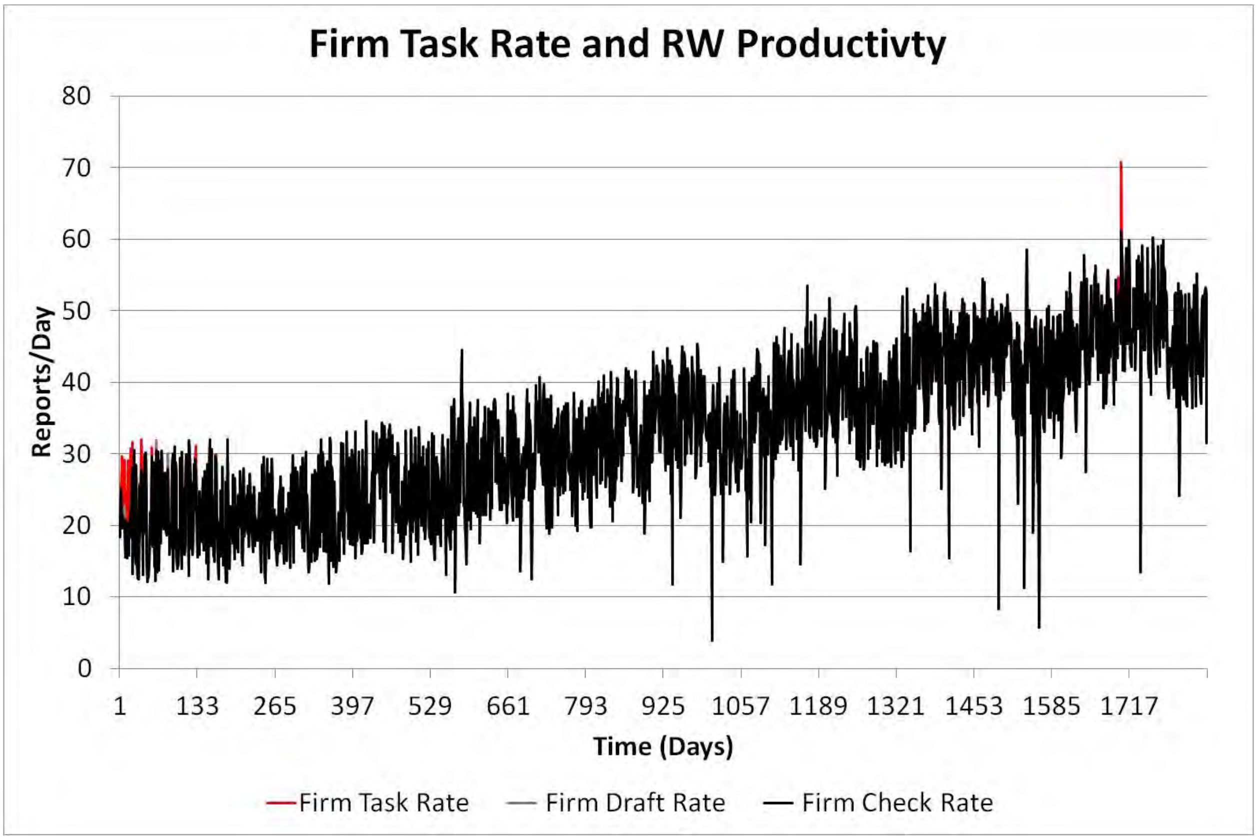


Figure 3.2: Firm Task Rate and RW Productivity

On initial analysis, we see that the task rate grows steadily over time from roughly 25 tasks per day to about 45 tasks per day over 7 years. There is a seasonal component to the task rate as we see the firm task rate slightly dip occasionally throughout the period of analysis. Another feature of the task rate are the sharp spikes and dips, showing that at any point the firm task rate can dip below and spike above its general trend. From our data collection and a series of workshops with management at the firm, we modelled the firm task rate as follows:

Task rate$_{ti}$ = Task rate$_{t0}$(1+ growth factor$_{jp}$*(1+crisis fraction$_{i}$)) where*

Task rate$_{t0}$ ~ U(min$_{p}$, max$_{p}$)

*Crisis fraction ~ U(0,0.05)*h, where h takes on the value 100% or -100% with equal probability*

For day i=1 to1849; year j=1 to 7; p=quiet period, normal period or busy period

Where the growth factor is the average year-on-year percentage increase in the number of reports for a specific period and crisis fraction is the unexpected percentage increase in the growth factor which has a 0 % to 5% chance of occurring. This equation we study in more detail in the next section to come.

As mentioned earlier, and as we can see from the figure above (Figure 3.2), the draft rate and check rate are dependent on the sum of individual productivity rates of RWers, where a RWer's productivity is dependent on the firm task rate, their skills set and the effect of qualitative variables on their productivity.

The simple formulation of an individual JRWDFTer, namely J1 JRWDFT, is as follows:

J1 JRWDFT draft rate$_{i}$ =

*min(J1 JRWDFT frac Tasks Incoming weight$_{i}$*Firm Task Rate$_{i}$, J1 JRWDFT Normal DR$_{i}$*(1+J1 JRWDFT QLV factor$_{i}$))*

for i day = 1 to 1849

In summary, the draft rate for J1 JRWDFT is dependent on the fraction of tasks that J1 JRWDFT receives (J1 JRWDFT frac Tasks Incoming weight$_i$*Firm Task Rate) and how well the JRWDFTer's productivity grows with experience, coupled with how qualitative variables affect his growth in productivity with experience (J1 JRWDFT Normal DR$_i$*(1+J1 JRWDFT QLV factor$_i$)).

In a similar way we model for SRWCHKer productivity. The main difference here is that SRWCHKer productivity is dependent on the draft rate as they check the drafts drafted by JRWDFTers.

S1 SRWCHK check rate$_i$ =

*min(S1 SRWCHK frac Tasks Incoming weight$_i$*Firm Draft Rate$_i$, S1 SRWCHK Normal DR$_i$*(1+S1 SRWCHK QLV factor$_i$))*

for i day = 1 to 1849

The data used in these equations is derived from data collection and a series of workshops with RWers (Appendix D).

3.1.2 Qualitative Modelling Overview

In the overview of quantitative modelling, we saw how draft rate and check rate are affected by qualitative variables (QLV factor). From literature and through a series of workshops we modelled for three (3) main qualitative variables for RWers, namely health, morale and stress, with a fourth variable, quality, incorporated for JRWDFTers.

The principle behind qualitative variables and their effect on productivity is that the qualitative variables take on values of between 0% and 100%. At various levels of each, the qualitative variables cause a percentage change in productivity through a multiplier effect. The formulation of the QLV factor is as follows:

J1 JRWDFT QLV Factor$_i$ =

*J1 JRWDFT MTProdDTh$_i$ *J1 JRWDFT hw$_i$+J1 JRWDFT MTProdDTm$_i$*J1 JRWDFT mw$_i$+J1 JRWDFT MTProdDTs$_i$*

**J1 JRWDFT sw$_i$+J1 JRWDFT MTProdDTq$_i$*J1 JRWDFT qw$_i$*

for i day = 1 to 1849

Here, MTProdDT stands for multiplier to productivity due health (h), morale, (m), stress (s) or quality (q), and J1 JRWDFT hw, J1 JRWDFT mw, J1 JRWDFT sw and J1 JRWDFT qw are the weights that each multiplier has on productivity, which sum up to 1. The values that the qualitative variables take on are dependent on various variables such as overtime worked (affecting health) and job satisfaction (affecting morale) that interact directly and indirectly with the numerous variables in the business process and with each other through feedback structures and inter-relationships (see Figure 3.8). The effect of qualitative variables on SRWCHK productivity is similar to the above with the exception of the quality variable.

S1 SRWCHK QLV Factor$_i$ =

*S1 SRWCHK MTProdDTh$_i$*S1 SRWCHK hw$_i$+S1 SRWCHK MTProdDTm$_i$*S1 SRWCHK mw$_i$+S1 SRWCHK MTProdDTs$_i$*S1 SRWCHK sw$_i$*

for i day = 1 to 1849

The weights on the multipliers are dependent on how much of an impact that a qualitative variable has on productivity in comparison to the other qualitative variables.

3.1.3 Workshops and Cognitive Mapping Overview

The workshops and cognitive mapping session with management were critical in shaping our model building and defining the objectives. These sessions facilitated the model building as we sought to evaluate management's strategic view of the business. The cognitive map helped to identify key areas in the business process based on management's goals and aspirations (Eden, 2004).

During our research period informal and formal workshops were held with various stakeholders each quarter of the year for the period starting January 2012 and ending December 2014. Through open discussions and questionnaires, we were able to conceptualise the business process, establish key variables in the business process and their dynamic structures, gather data and conduct feedback session in relation to the models built. The workshops facilitated the development of the general model to be used in this study.

Concurrently, we conducted a cognitive mapping session with management using principles from Eden (2004). The session focused on how the firm has grown over time, looking specifically into capacity and workload. We examined threats to the business and growth strategies that were adopted. We also wanted to gain insight into areas where management sees the firm in a few years' time. The transcripts from the cognitive mapping session were then translated into a cognitive map, which was first drawn up by the writer and later revised with the aid of management. The process of building the cognitive map is documented in section 3.4 of this chapter.

3.2 Quantitative Modelling

3.2.1 Building in the Task Rate

The task rate gives the number of tasks per day that the firm receives. We make use of the firm's initial datasets on the firm's tasks per month for the period of 2012 and 2013, coupled with management's expert opinion, to estimate the task rate (rate of flow of incoming work) over a 7 year period, starting from year 1 (2012). The initial year of our simulation makes use of the 2012 dataset, using data from January to December 2012. Table 3.1 shows the parameters we made use of in modelling for our initial year and also specifies the periods that management and the data suggests as being normal, quiet and busy periods within the year. We estimated 22 working days within each month.

We studied each period indicated in Table 3.1 to see what the mean, minimum and maximum task rate per day was during each period. Starting from the base year, we assumed that for each period the task rate can take on any value between the minimum and maximum value with equal probability.

Period	Months of Period	Mean (reports/day)	Min (reports/day)	Max (reports/day)
Normal	February to April; June to September	16.8	12.1	18
Quiet	December; January	7.9	6.9	8.9
Busy	May; October to November	26.8	25.7	27.0

Table 3.1: Firm Task Rate for Base Year

The year-on-year growth rate of the firm's inflow of work is calculated using data for the period of 2012 and 2013 (Appendix D), as well as management's opinion on their sense of how the firm will grow over time. The observed year-on-year percentage increase in the number of reports in each period from 2012 to 2013 was as follows:

- Quiet Period - 24%
- Normal Period - 48%
- Busy Period - 10%

These growth factors were incorporated into our model. We went further and incorporated management's postulation with regards to how they expect the number of reports to progress in the future taking into account potential influxes in the inflow of work or falls in the inflow of work. Management postulates that in any given month there is at most a 5% chance that the task rate will increase by 100% more than expected or decrease by 100% more than expected, with the postulations based on client retention and client recruitment. Therefore, the task rate per day for year *i* is denoted as follows:

$Task\ rate_{ti} = Task\ rate_{p0} * (1 + growth\ factor_{jp} * (1 + crisis\ fraction_i))$ *where*

$Task\ rate_{t0} \sim U(min_p, max_p)$

*Crisis fraction ~ U(0,0.05)*h, where h takes on the value 100% or -100% with equal probability*

For day i=1 to1849; year j=1 to 7; p=quiet period, normal period or busy period

Where the *growth factor* is the average year-on-year percentage increase in the number of reports for a specific period and *crisis fraction* is the unexpected percentage increase in the *growth factor* which has a 0 % to 5% chance of occurring. Figure 3.3 illustrates the Vensim display of the task rate.

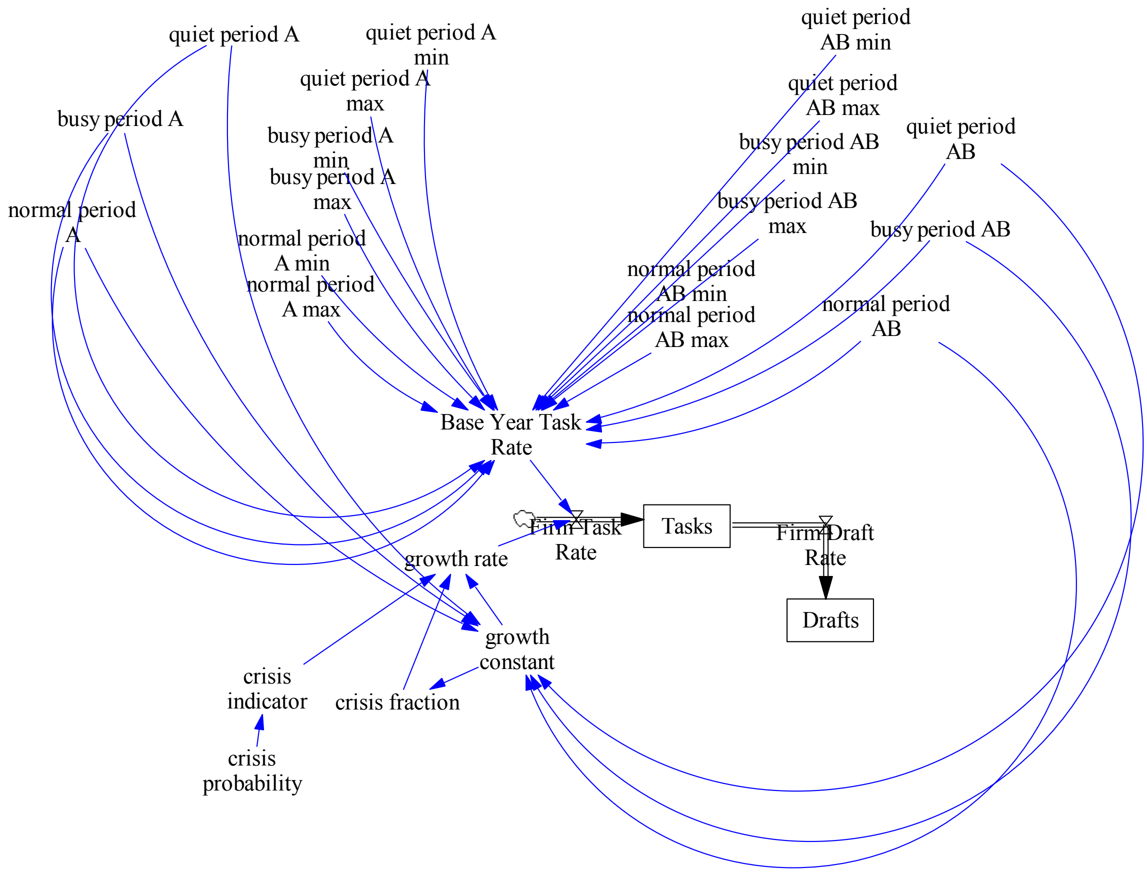


Figure 3.3: Vensim Diagram of Task Rate

3.2.2 Building in the Draft Rate and Check Rate

Reverting to the overview of the quantitative modelling overview, we established that for an individual JRWDFTer, J1 JRWDFT, the main equation driving this draft rate is given as follows (rate is per/day):

J1 JRWDFT draft rate$_i$ =

*min(J1 JRWDFT frac Tasks Incoming weight$_i$*Firm Task Rate$_i$, J1 JRWDFT Normal DR$_i$*(1+J1 JRWDFT QLV factor$_i$))*

for i day = 1 to 1849

Here, the draft rate for J1 JRWDFT is dependent on the fraction of tasks that J1 JRWDFT receives (J1 JRWDFT frac Tasks Incoming weight$_i$*Firm Task Rate) and how well the JRWDFTer's productivity grows with experience, coupled with how qualitative variables affect his growth in productivity with experience (J1 JRWDFT Normal DR*i**(1+J1 JRWDFT QLV factor)). We give a breakdown of the above equation to get a better understanding of the quantitative variables determining the draft rate.

The minimum function in the equation is a constraint on an individual J1 JRWDFTer which ensures that in the case that when his draft rate capability, J1 JRWDFT Normal DR$_i$*(1+J1 JRWDFT QLV factor$_i$), is higher than the number of tasks allocated to him, J1 JRWDFT frac Tasks Incoming weight$_i$*Firm Task Rate$_i$, then he only drafts at the required rated. The opposite applies, where if the draft rate required of him is higher than what he is capable of drafting then J1 JRWDFT Normal DR$_i$*(1+J1 JRWDFT QLV factor$_i$) prevails.

The variable JRWDFT Normal DR$_i$ is the general growth in draft rate of JRWDFTers over time based on past data and information provided by JRWDFTers. The equation for an individual JRWDFTer, J1 JRWDFT, for JRWDFT Normal DR is given as follows:

J1 JRWDFT Normal DR$_i$ =

min((J1 JRWDFT initial DR$_i$+ J1 JRWDFT growth rate DR$_i$),J1 JRWDFT max)

for i day = 1 to 1849

This equation explains how for an individual J1 JRWDFTer, his draft rate starts at an initial base level and with growing experience it increases over time. The draft rate does not increase infinitely but reaches a maximum after some time. J1 JRWDFTer is not capable of drafting at a higher rate than this regardless of experience. Appendix D gives the data used. Figure 3.4 gives an illustration of how J1 JRWDFT Normal DR$_i$ progresses with time as modelled in Vensim.

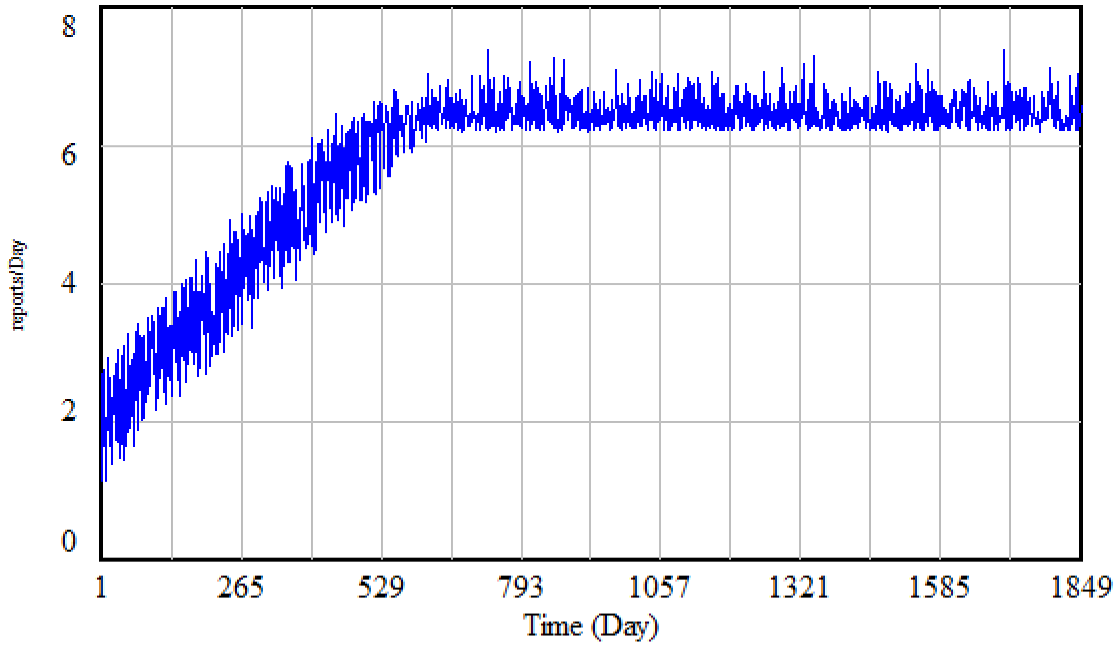


Figure 3.4: J1 JRWDFT Normal DR over time

J1 JRWDFT initial draft rate is roughly 2 reports per day and over time is increasing to over 6 reports per day as a maximum. It must be noted that an increase in the number of working hours, through overtime increases J1 JRWDFT draft rate. In the instance where JRWDFTers have to work overtime, this triggers the following variable J1 JRWDFT Normal DR_i overtime (see Appendix C).

J1 JRWDFT frac Tasks Incoming weight gives the fraction of daily tasks allocated to J1 JRWDFT.

J1 JRWDFT frac Tasks Incoming weight$_i$ =

if then else(Time=1,1/Number of JRWDFT$_i$, J1 JRWDFT frac Tasks Incoming$_i$ /JRWDFT frac Tasks Incoming$_i$)

for i day = 1 to 1849

On day 1, the tasks are split evenly amongst the JRWDFTers. From then on the number of tasks allocated to J1 JRWDFT is dependent on J1 JRWDFT frac Tasks Incoming$_i$ with J1 JRWDFT frac Tasks Incoming$_i$ dependent on J1 JRWDFT Normal Draft Rate and how qualitative variables affect his productivity in relation to other JRWDFTers (see Appendix C). Hence, the more potentially productive J1 JRWDFTer is in relation to the rest of the JRWDFTers, the more tasks that are allocated to him. Figure 3.5 illustrates the fraction of tasks allocated to J1 JRWDFT over time when there are 10 JRWDFTers with the same level of experience.

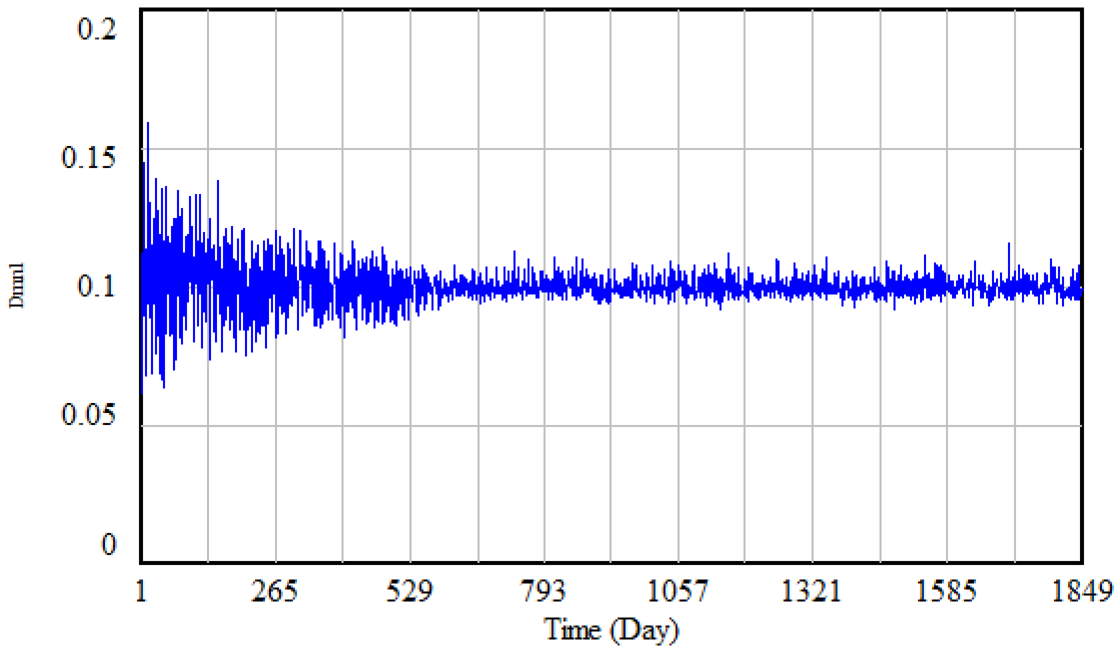


Figure 3.5: J1 JRWDFT fraction of incoming tasks over time

The effect of qualitative variables initially affects the fraction of tasks allocated as RWers initially struggle to keep up with the required task rate. Over time as they are able to cope with the task rate the fraction of incoming task rate stabilises around 0.1 (10%) which is 1/ number of JRWDFTers.

In a similar way we modelled for the check rate for SRWCHKers.

$S1\ SRWCHK\ check\ rate_i =$

$min(S1\ SRWCHK\ frac\ Tasks\ Incoming\ weight_i * Firm\ Draft\ Rate_i\ , S1\ SRWCHK\ Normal\ DR_i * (1 + S1\ SRWCHK\ QLV\ factor_i))$

$for\ i\ day = 1\ to\ 1849$

Figure 3.6 gives an illustration of how S1 SRWCHK Normal CR_i progresses with time as modelled in Vensim. The maximum draft rate is around 15 reports per day subject to variation. Figure 3.7 illustrates the fraction of task allocated to S1 SRWCHK over time when there are 5 SRWCHKer with the same experience.

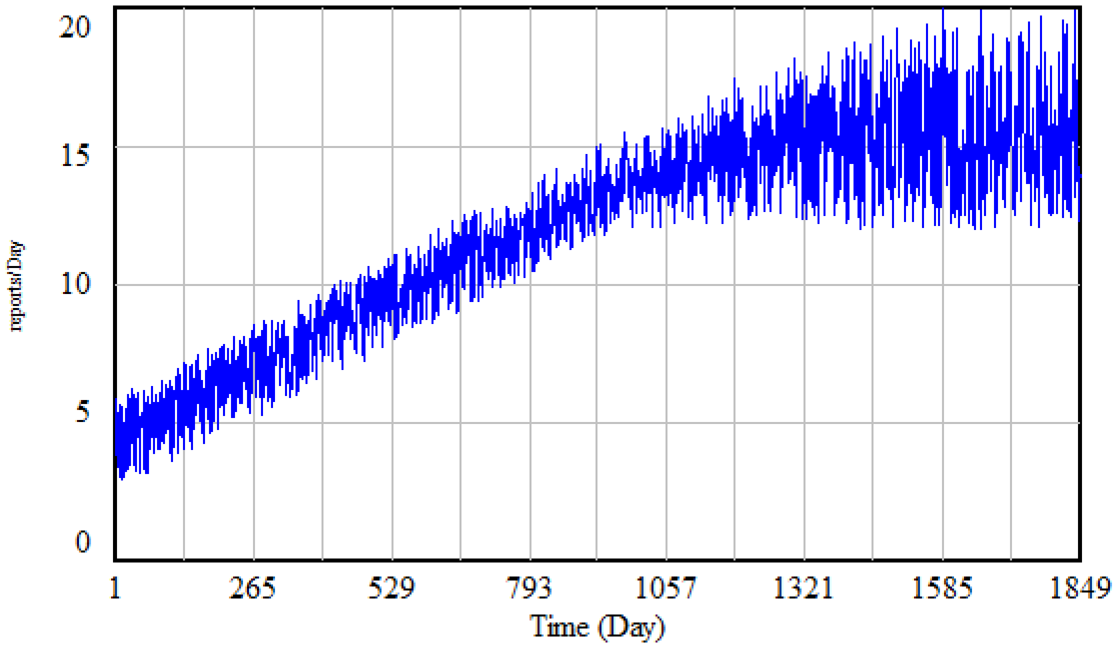


Figure 3.6: S1 SRWCHK Normal CR over time

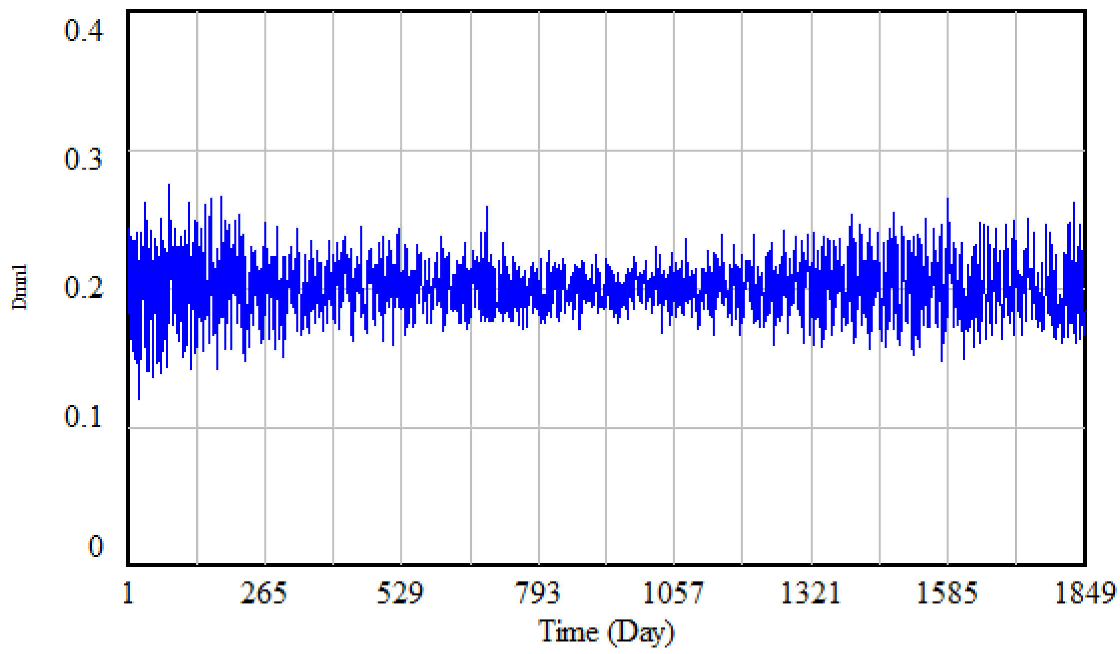


Figure 3.7: S1 SRWCHK fraction of incoming tasks over time

3.3 Qualitative Modelling

The qualitative variables have a multiplier effect on individual RWers' productivity. Productivity is affected by changing levels of the qualitative variables.

Figure 3.8 gives a simple model schematic of how the qualitative variables health, morale, stress and quality respectively, interact with each other, as well as how they interact with RWer productivity. Each of the qualitative variables (health, morale, stress and quality) is affected by latent variables such as exhaustion, job satisfaction and job stress. For completeness, we also illustrate other key quantitative variables that affect productivity. The full models that we built in Vensim can be seen in Appendix D. The equations governing the qualitative variables and their inter-relationships with each other and other latent variables are outlined later on in this section and explained in section 3.4 of this chapter. At the end of section 3.4, we highlight some of the feedback loops governing the behaviour of the qualitative variables.

JRW growth rate and *JRW growth max* shown in Figure 3.8 below are described and illustrated on page 47 (*J1 JRWDFT growth rate* DR_i and *J1 JRWDFT max*) and Figure 3.4. The other variables are explained in more detail in this section.

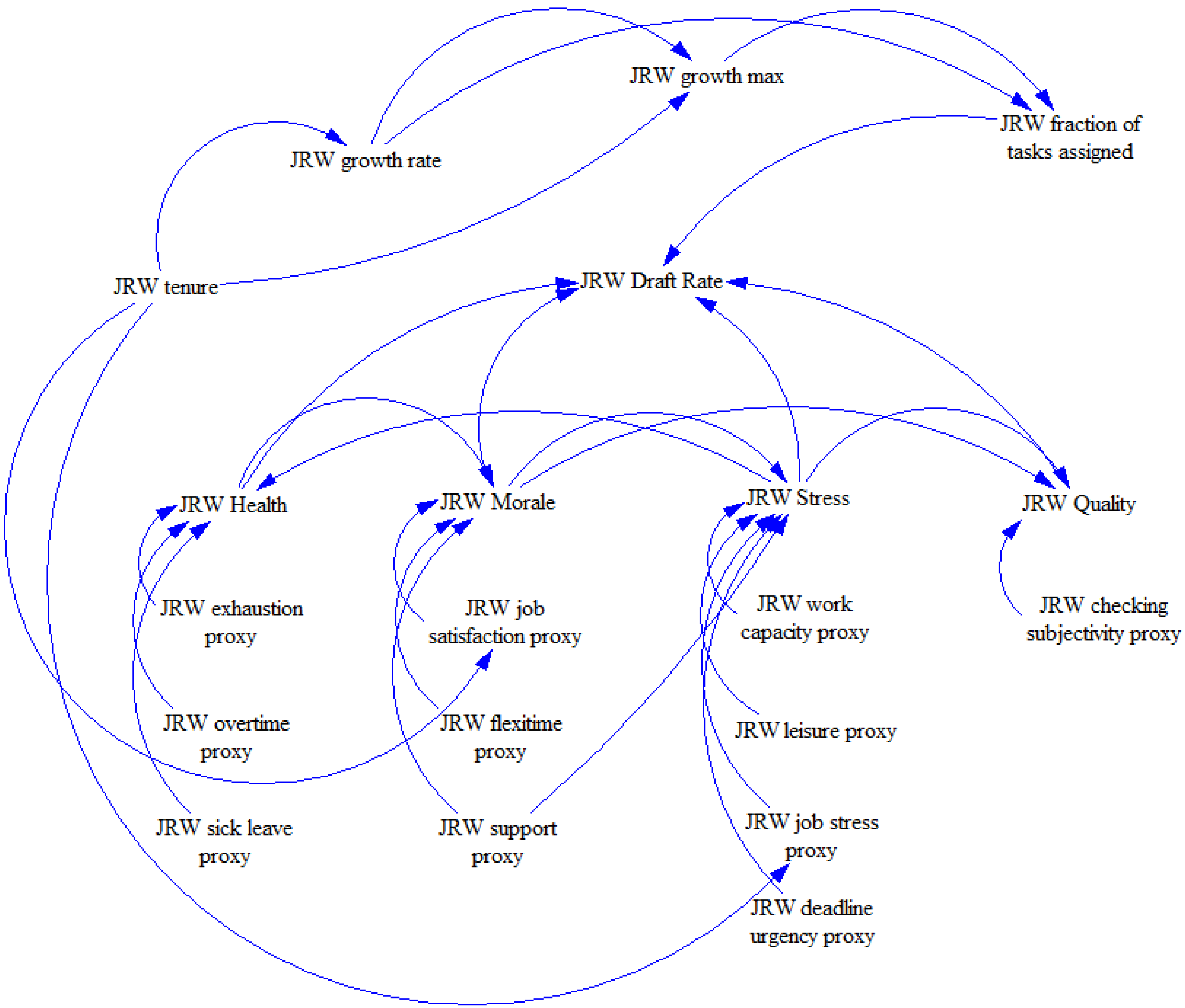


Figure 3.8: Model schematic diagram showing how qualitative variables, and other key quantitative variables, affect RWer productivity

Reverting to the equation governing JRWDFTer draft rate, we see that the qualitative variables affects J1 JRWDFTer's drafting capability through J1 JRWDFT QLV factor and also affects the J1 JRWDFT frac Tasks Incoming weight as we discussed in the previous section. Qualitative variables affect SRWCHKer productivity in a similar way.

J1 JRWDFT draft rate$_i$ =

*min(J1 JRWDFT frac Tasks Incoming weight$_i$*Firm Task Rate$_i$,J1 JRWDFT Normal DR$_i$*(1+J1 JRWDFT QLV factor$_i$))*

for i day = 1 to 1849

In more detail we equate the QLV factor JRWDFTers, namely for J1 JRWDFT, as follows:

J1 JRWDFT QLV Factor$_i$ $_{(\text{min}=-100\%,\ \text{max}=100\%)}$ =

*J1 JRWDFT MTProdDTh$_{ik}$ *J1 JRWDFT hw$_{ik}$+J1 JRWDFT MTProdDTm$_{ik}$*J1 JRWDFT mw$_{ik}$+J1 JRWDFT MTProdDTs$_{ik}$*

**J1 JRWDFT sw$_i$+J1 JRWDFT MTProdDTq$_i$*J1 JRWDFT qw$_i$*

for i day = 1 to 1849, for k level = 0% to 100% and J1 JRWDFT hw + J1 JRWDFT mw + J1 JRWDFT sw + J1 JRWDFT qw = 1

where J1 JRWDFT MTProdDTh$_{ik}$, J1 JRWDFT MTProdDTm$_{ik}$, J1 JRWDFT MTProdDTs$_{ik}$, and J1 JRWDFT MTProdDTq$_i$

given the percentage change in productivity brought about by the change in the percentage levels (k) of health, morale, stress and quality, respectively, denoted as J1 JRWDFT **M**ultiplier **T**o **Prod**uctivity **D**ue **T**o **h**ealth (h), **m**orale (m), **s**tress (s) and **q**uality (q) respectively. J1 JRWDFT hw, J1 JRWDFT mw, J1 JRWDFT sw and J1 JRWDFT qw are the weights placed on the impact that health, morale, stress and quality levels have on productivity respectively. In a similar way we modelled for SRWCHKers (Appendix C).

The percentage effect that the qualitative variables have on productivity is based on questionnaire results given by RWers, with RWers estimating what they believe to be the percentage change in productivity brought about by changes in the level of each qualitative variable (data in Appendix D). That is to say that if the level of a qualitative variable is within a certain range X, the unweighted change in productivity is Y.

The figures below (Figure 3.9 to Figure 3.12) illustrate the changes in the qualitative variable health of J1 JRWDFT and S1 SRWCHK and the weighted multiplier effect of each qualitative variable on productivity.

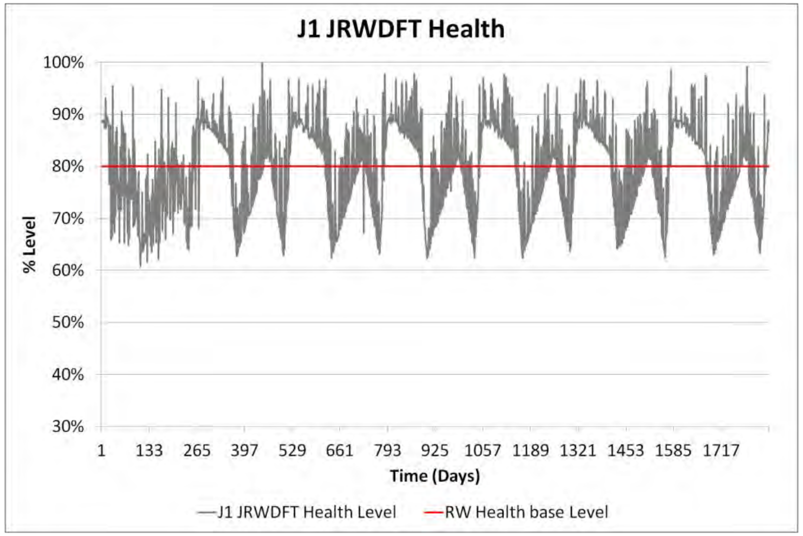


Figure 3.9: J1 JRWDFT Health Level

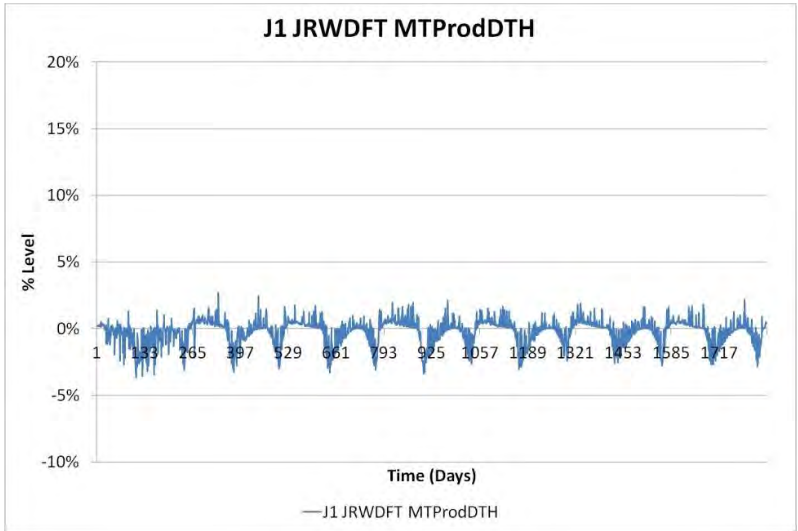


Figure 3.10: J1 JRWDFT MTProdDTH

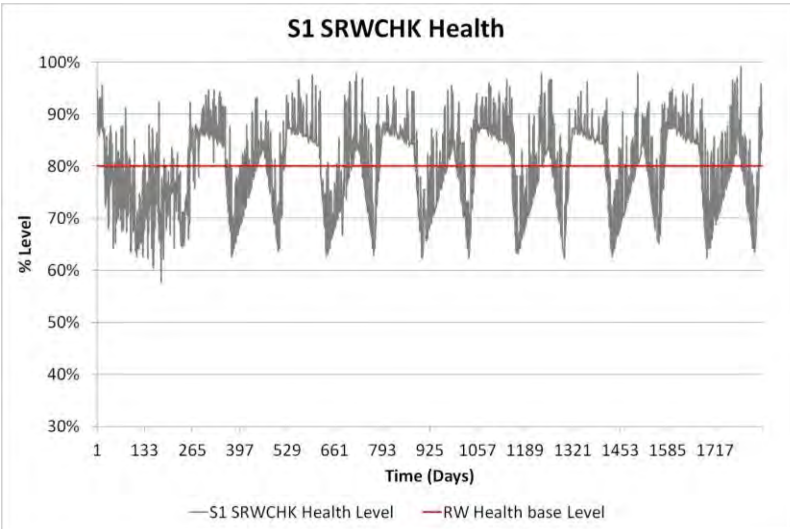


Figure 3.12: S1 SRWCHK Health Level

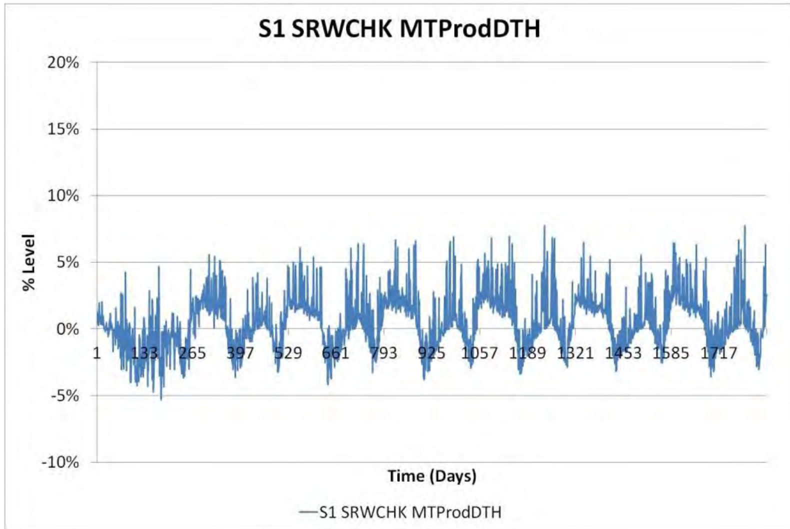


Figure 3.11: S1 SRWCHK MTProdDTH

We now take a look at the variables that bring about the changes in the level of each qualitative variable as we saw in the figures above (Figure 3.8 to Figure 3.8). We use J1 JRWDFT as an example.

J1 JRWDFT health level$_i$ $_{(min=0\%,\ max=100\%)}$ *= J1 JRWDFT health base*(1 + J1 JRWDFT MThDTexh$_{ik}$*J1 JRWDFT exhw$_{ik}$ + J1 JRWDFT MThDTov$_{ik}$*J1 JRWDFT ovw$_{ik}$ + J1 JRWDFT MThDTsick$_{ik}$* J1 JRWDFT sickw$_{ik}$ +J1 JRWDFT MThDTs $_{ik}$* J1 JRWDFT sw$_{ik}$)*

for i day = 1 to 1849, for k level = -100% to 100% and J1 JRWDFT exhw + J1 JRWDFT ovw + J1 JRWDFT sickw + J1 JRWDFT sw = 1

where **J1 JRWDFT health level$_i$** gives the health levels due to the combined effect of changing levels (k) of exhaustion, overtime, sick leave and stress, respectively. The variables are denoted as J1 JRW **M**ultiplier **T**o **h**ealth **D**ue **T**o overtime (ov), exhaustion (exh), sick leave (sick) and stress (s) respectively. J1 JRWDFT health base is the health level that brings about no change in productivity, in other words, J1 JRWDFT MTProdDTH is zero. Deviations from this base level are then brought about by changes in the variables stated above.

J1 JRWDFT morale level$_i$ $_{(min=0\%,\ max=100\%)}$ *= J1 JRWDFT morale base*(1 + J1 JRWDFT MTmDTjobsat$_{ik}$*J1 JRWDFT jobsatw$_{ik}$ + J1 JRWDFT MTmDTflex$_{ik}$*J1 JRWDFT flexw$_{ik}$ + J1 JRWDFT MTmDTh$_{ik}$* J1 JRWDFThw$_{ik}$ +J1 JRWDFT MTmDTsupp $_{ik}$* J1 JRWDFT suppw$_{ik}$)*

for i day = 1 to 1849, for k level = -100% to 100% and J1 JRWDFT jobsatw + J1 JRWDFT flexw + J1 JRWDFT hw + J1 JRWDFT suppw = 1

where **J1 JRWDFT morale level$_i$** gives the morale levels due to the combined effect of changing levels (k) of exhaustion, overtime, sick leave and stress, respectively. The variables are denoted as J1 JRW **M**ultiplier **T**o **morale** **D**ue **T**o job satisfaction (jobsat), flexitime (flex), health (h), support (supp) respectively. J1 JRWDFT morale base is the morale level that brings about no change in productivity, in other words, J1 JRWDFT MTProdDTm is zero. Deviations from this base level are then brought about by changes in the variables stated above.

J1 JRWDFT stress level $_{i\ (min=0\%,\ max=100\%)}$ *= J1 JRWDFT stress base*(1 + J1 JRWDFT MTsDTwcap*$_{ik}$**J1 JRWDFT wcapw*$_{ik}$ *+ J1 JRWDFT MTsDTsupp*$_{ik}$**J1 JRWDFT suppw*$_{ik}$ *+ J1 JRWDFT MTsDTleis*$_{ik}$** J1 JRWDFTleisw*$_{ik}$ *+J1 JRWDFT MTsDTjobstress* $_{ik}$** J1 JRWDFT jobstressw*$_{ik}$ *+J1 JRWDFT MTsDTurgent*$_{ik}$** J1 JRWDFT urgentw*$_{ik}$*)*

for i day = 1 to 1849, for k level = -100% to 100% and J1 JRWDFT wcapw + J1 JRWDFT suppw + J1 JRWDFT leisw + J1 JRWDFT jobstressw + J1 JRWDFT urgentw = 1

where **J1 JRWDFT stress level**$_{\mathbf{i}}$ gives the stress levels due to the combined effect of changing levels (k) of work capacity, support, leisure time, job stress and urgent tasks, respectively. The variables are denoted as J1 JRW **M**ultiplier **T**o **stress** **D**ue **T**o job work capacity (wcap), support (supp), leisure (leis), job stress (jobstress) and urgent tasks (urgent) respectively. J1 JRWDFT stress base is the stress level that brings about no change in productivity, in other words, J1 JRWDFT MTProdDTs is zero. Deviations from this base level are then brought about by changes in the variables stated above.

J1 JRWDFT quality level $_{i}$ ***(*** $_{min=0\%,\ max=100\%}$ ***)*** *= min((J1 JRWDFT initial QLT + J1 JRWDFT QLT growth constant+J1 JRWDFT MTqDsubj*$_{ik}$ **J1 JRWDFT SLD*$_{ik}$*)*(1+J1 JRWDFT MTqDTm*$_{ik}$ **J1 JRWDFT MTqDTmw*$_{ik}$ **J1 JRWDFT SLD*$_{ik}$ *+J1 JRWDFT MTqDTs*$_{ik}$ **J1 JRWDFT MTqDTsw*$_{ik}$ **J1 JRWDFT SLD*$_{ik}$*),1)*

for i day = 1 to 1849, for k level = -100% to 100% and J1 JRWDFT MTqDTmw$_{ik}$ *+ J1 JRWDFT MTqDTsw*$_{ik}$ *= 1*

In this instance **J1 JRWDFT quality level**$_{\mathbf{i}}$ is determined by the growth in quality over time to 100%, starting from an initial value, J1 JRWDFT initial QLT. Qualitative variables affecting this growth are subjectivity in grading drafts by SRWCHKers (subj), morale levels (m) and stress levels (s). The effect of these qualitative variables diminishes over time through the J1 JRWDFT SLD variable (straight line decrease). Below is an illustration of the quality level of J1 JRWDFT over time. The level progresses from an initial level of around 70% to 100%, with the variation in the levels decreasing with increasing experience as shown in Figure 3.13.

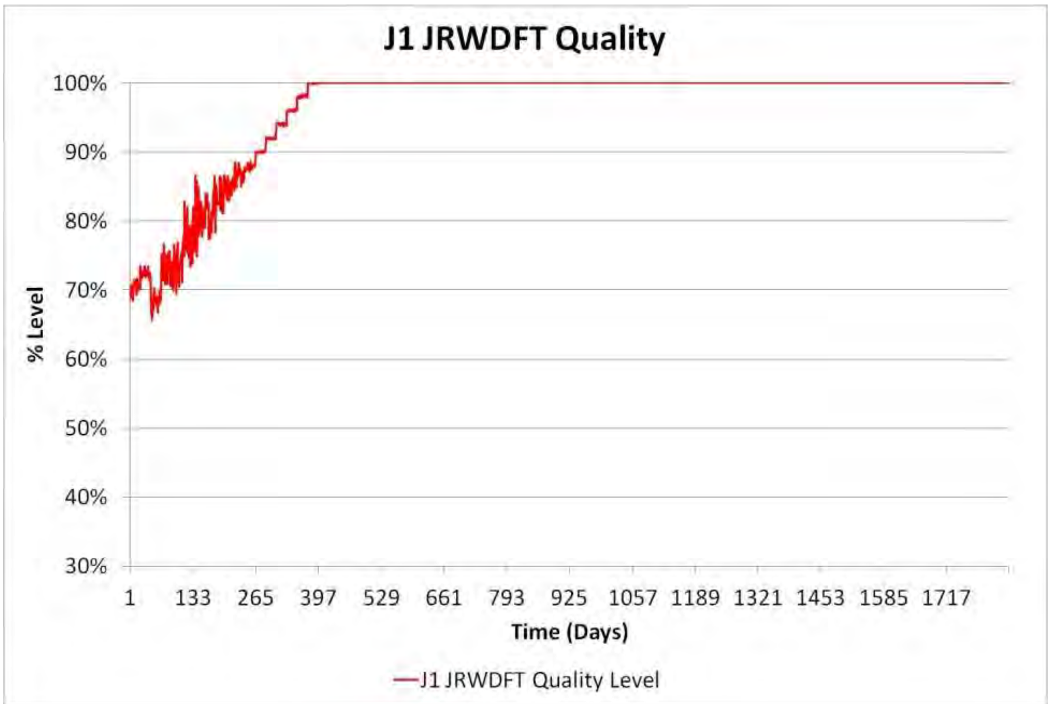


Figure 3.13: J1 JRWDFT Quality Level

In a similar way we modelled for SRWCHKer qualitative variables for health, morale and stress (Appendix C).

3.4 Workshops and Cognitive Mapping

The workshops, mainly with RWers, formed the basis from where we obtained data and information from which we used to understand and model the business process at the firm. The cognitive mapping sessions also gave us an understanding of how the business process has developed over time from management's perspective, and how the process is expected to develop over time. We evaluate the business process through model simulations keeping in mind the areas that management believe to be important in us forming a better understanding of the behaviour of the business process.

Table 3.2 details the workshops and cognitive mapping sessions conducted in the model building process over the research period. Our analysis runs for seven years, with our base year using data collected from the year 2012 when the firm started showing constant and steady growth patterns.

The data on the inflow of work from 2012 and 2013, in combination with information gathered from the cognitive mapping session to be discussed, gives us an idea of the growth rate of the firm's task rate over the years of analysis. The data also gives us an idea of the seasonality of the firm's business with regards to inflow of work (task rate), where we were able to distinguish between the quiet, normal and busy periods in the year. These periods are also later confirmed by management in the cognitive mapping session.

Year	Quarter	Agenda Item/ Stage in Model Building	Parties Involved	Outcome
2012	1st and 2nd	Using the firm as a case study.	Management and the writer	General overview of business process modelling and model simulations outlined and its relevance in modelling the firm's business approach.
2012	3rd	Establishing key variables in the firm's business process.	RWers	Discussed the general process. Established key variables in the process and depicted the simple model of the process. First mention of the possibility of qualitative variables affecting productivity.
2012	4th	Going over literature in SD and business process modelling.	The writer	Achieved better understanding of business process modelling and suimualtions, and various other business process modelling techniques. Verification that business process modelling and model simulations are potentially suitable approaches given the business process at the firm.
2013	1st	Data collection. Questionnaires.	Stakeholders	Gathered data on firm's work inflow and data on RWers' productivity. Established key variables affecting firm work inflow and variables affecting RWers' productivity. Formulated equations and inter-relationships within the model.
2013	2nd	Seminar on research topic at University of Cape Town.	The writer and academics in statistical sciences	Presented research progress and findings. Received feedback with regards to areas that were not clear.
2013	3rd	Cognitive Map Session.	The vice president of the firm	Documented the history of the firm and how it reached its current state. Established long term objectives of the firm and the firm's areas of concern.
2013	4th	Model building feedback session.	Stakeholders	Final model presented and feedback given. First signs that feedback loops may not have a significant impact on behaviour of the system.

Year	Quarter	Agenda Item/ Stage in Model Building	Parties Involved	Outcome
2014	1st and 2nd	Model corrections.	The writer	Corrections made to final model.
2014	3rd	Model feedback session.	Stakeholders	Final model presented and approved. Concluded that process has feedback loops, but not all have significant impact on behaviour of the system (see result chapter – Chapter 5).
2014	4th	Research write up.	The writer	Write up of findings.

Table 3.2: General overview of Data Collection and Modelling of the Business Process

The sections that follow review the workshops involving the data collection and discussions around the general model and its quantitative variables and qualitative variables.

Data Collection – Draft Rate and Check Rate

From the writer's general understanding of the firm's business process, we drafted a questionnaire for RWers to fill, answering questions around the key variables governing the business process (Appendix D). We then collected data on the variables. The questionnaires also allowed for RWers to add or comment on the questions asked, in case key questions were missed or questions in the questionnaire could be asked better. This allowed RWers to offer their own unique perspective on the process. The questionnaire session started with JRWDFTers who had been hired by the firm in the first quarter of 2012 (5 JRWDFters), with the session starting with the writer explaining the purpose of the questionnaire (for research purposes). The writer also took the group through the objectives that the models were intended to answer.

From the discussions and questionnaires completed by JRWDFters we were able to establish that the governing variables and skills set that determined an individual JRWDFTer's draft rate was as follows (excluding qualitative variables):

- Initial draft rate – number of reports drafted per day at beginning of tenure
- Growth of draft rate – improvements in draft rate over time
- Current draft Rate – as at the end of 2013

- Maximum draft rate – RWers maximum draft rate that they can operate at if they had could compromise on quality of reports

- General urgency of reports done

- Predicted time to progress to role of drafting and sending their own reports

- Equations and inter-relationships between qualitative variables

Data on these was gathered from the JRWDFTers. In our model we used this data to build a generic JRWDFT prototype. In most cases, a normal distribution was used. Our dissertation will highlight the variables where a normal distribution was not used.

A similar exercise was done with SRWCHKers as well with the focus being on their check rate. From this session with SRWCHKers we were able to obtain the following variables and estimates:

- Initial check rate – number of reports checked per day at beginning of tenure

- Growth of check rate – improvements in check rate over time

- Current check Rate – as at the end of 2013

- Maximum check rate – RWers maximum check rate that they can operate at if they had could compromise on quality of reports

- General urgency of reports done

- Equations and inter-relationships between qualitative variables

Data Collection – Qualitative Variables

The concept of modelling qualitative variables was discussed with RWers, making reference to literature on modelling qualitative variables with respect to their impact on productivity. We drafted a list of possible qualitative variables that could directly affect productivity from our research from literature, namely (Lyneis & Ford, 2007) and (Li, 2008), and discussions held with RWers (5 JRWDFTers and 6 SRWCHKers). Each variable brought forward was then defined (Appendix D), and in our case the definitions were based on oxford dictionary and a discussion was held over possible factors affecting each variable. These factors were noted down. A questionnaire was then drafted around qualitative variables. From our literature we saw how Marcoulides & Heck (1993) modelled for organizational culture incorporating five interrelated latent variables, namely Organizational structure/purpose (OS), Organizational values (OV), Organizational climate (OC), Task organization (TO) and Worker attitudes/goals (AT) of which each variables is measured by various underlying variables. In a similar way, RWers were asked to list the three qualitative variables that would affect their productivity the most. From the responses we gathered the top three most picked variables. The variables and definitions were as follows (Oxford English Dictionary, 2008):

Health (burnout) - Physical or mental collapse caused by overwork or stress

Example: *high levels of professionalism which may result in burnout*

Morale - The confidence, enthusiasm, and discipline of a person or group at a particular time

Example: *the team's morale was high*

Stress - A state of mental or emotional strain or tension resulting from adverse or demanding circumstances

Example: *he's obviously under a lot of stress*

We added a fourth variable for JRWers, which was Quality. This is a percentage out of 100% given to JRWDFTers by SRWCHKers with regards to the quality of each report that they drafted in accordance to a score sheet which deducts marks for errors such as mistakes in calculating the claims and mistakes in the drafted reports, for example misspelling or incorrectly copying over information into the draft. The variable is then actually measured quantitatively.

Once we had established the qualitative variables we wished to incorporate into the model, we incorporated the factors affecting these qualitative variables given discussion held with RWers, ensuring that the relationships were logical and significant with regards to the objectives we had in mind for the model. We then allocated a scale to the three main qualitative variables. There was no standardized unit of measure for each variable so we allocated a scale to each using a 5-point unit scale for each (Akkermans, 1995). For example, for stress levels we had a scale as follows:

$X \leq 20\%$ - not so stressed

$X \leq 40\%$ - marginally stressed

$X \leq 60\%$ - stressed but ok

$X \leq 80\%$ - stressed and in need of a break

$X \leq 100\%$ - very stressed

The scales for the other variables can be views in Appendix D.

The discussion that followed with RWers was now around how much of an impact RWers believed that the qualitative variables had on productivity. For each of the 5 points in the scale the RWers were asked how much of a percentage increase or decrease in productivity would result. With the aid of a graph, RWers were able to allocate the percentage change in productivity that would result from a change in the level of each qualitative variable. This method was taken from Akkermans (1995) as reviewed in the literature review

The graphical functions for JRWDFTers' multiplier to productivity due to health, morale, stress and quality respectively are illustrated below (Figure 3.14 to Figure 3.17) as modelled in Vensim. The input is the level in the qualitative level and the output is the multiplier effect on productivity due to the qualitative variable. The graphical functions for SRWCHKers can be viewed in Appendix D.

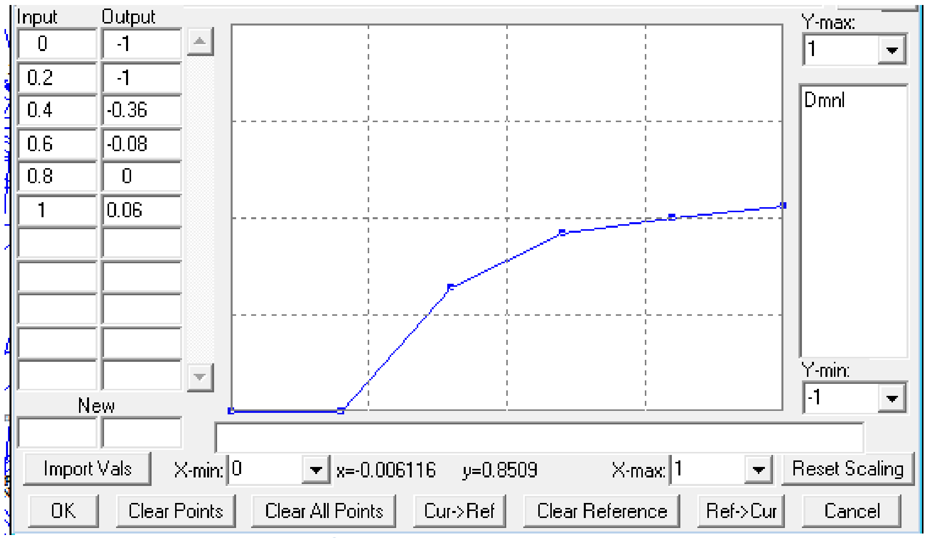


Figure 3.14: Graphical Function for JRWCHK MTProdDTH

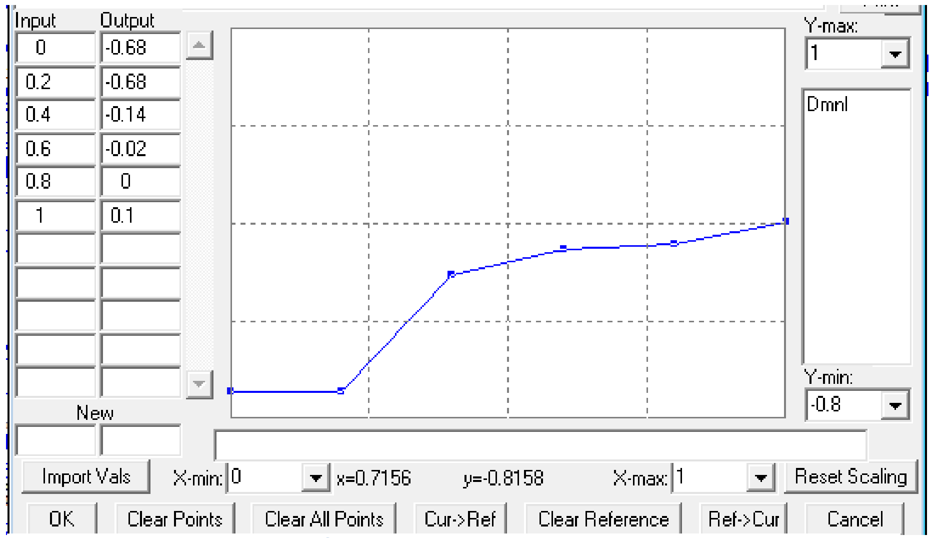


Figure 3.15: Graphical Function for JRWCHK MTProdDTM

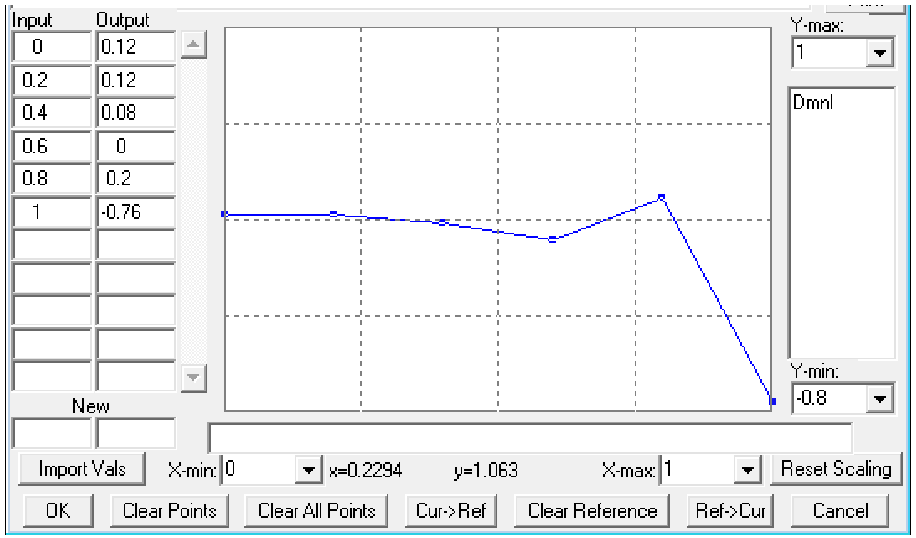


Figure 3.16: Graphical Function for JRWCHK MTProdDTS

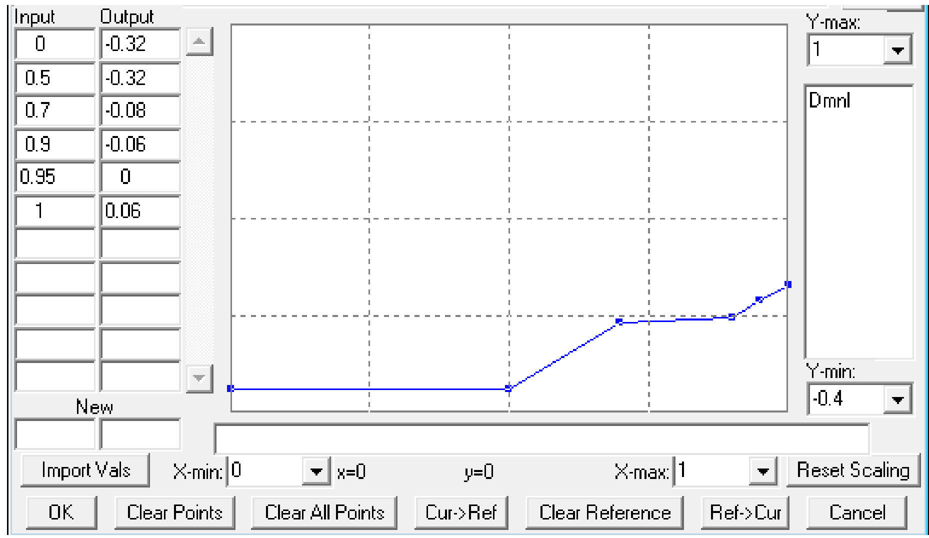


Figure 3.17: Graphical Function for JRWCHK MTProdDTQ

The graphical function for health shows how at low levels of health, below base level (80%), the effect on productivity would be negative, assuming 100% weighting on MTProdDTH. At higher levels of health above 80% the effect on productivity would be positive. This is the same for morale. However, the effect of health at low levels (0%) is more adverse compared to morale, with a -100% change in productivity for health levels at 0% and a -68% change in productivity for morale levels at 0%. At 100% morale, however, the effect of morale on productivity is higher (10%) than that of health (6%) at 100% health. For stress, the multiplier effect on productivity increases from base level stress to 0% stress. Stress has its greatest impact on productivity, assuming 100% weighting on MTProdDTS, when at 80%. As stress levels increase beyond 80%, the multiplier effect decreases rapidly to -76%, when stress is 100%. The multiplier effect of quality on productivity has the lowest negative effect on productivity when at its lowest level (MTProdDTQ is -32%) as well as one of the lowest positive effect when at its highest level (MTProdDTQ is 6%) amongst the JRWDFTer qualitative variables.

The weights on the multipliers are dependent on how much of an impact that a qualitative variable has on productivity in comparison to the other qualitative variables. It must be noted that at extreme levels of health or morale (less than 20%) or stress (plus 80%), the weighting on its multiplier effect on productivity increases to 100%. That is to say, for example, if someone is extremely unhealthy, their productivity will most likely solely be affected by health and its multiplier on productivity, with changes in other levels unlikely to change their productivity.

We then looked into each qualitative variable and the factors affecting them, establishing the relationship and data or information to be used to measure them.

As mentioned earlier, the factors **affecting health levels** in this case are overtime, exhaustion, sick leave days and stress. In the same questionnaire asking RWers about how qualitative variables affected productivity, RWers were asked to estimate the average percentage decrease in health levels (exhaustion levels) dependent on the period of the year (quiet, normal and busy) from the health base level (80%).

In addition to that, we asked how much of an impact overtime had on exhaustion levels. Sick leave days acted as a proxy for external factors affecting health. This is to say that certain factors affecting health, outside of work-related factors, affect a RWer's productivity whilst at work. Factors such as regular/irregular visits to the doctor, proper/improper dieting or regular/irregular exercise fall under external factors affecting health levels. We modelled sick leave days from information gathered on the average number of sick leave days taken within a calendar year. The impact sick leave days has on health level is dependent on whether RWers take more or less days than the mean number of days drawn from the sample. For the impact of stress on health, RWers highlighted how severe levels of stress can contribute towards a decline in heath. We modelled for the impact of stress levels on health only for stress levels above 80% (highest range). Outside of this range of stress, stress has a nil impact on health. The variables and factors were modelled around a normal distribution.

For morale, the base level was established at 80%. We stated that job satisfaction, flexitime, health levels and support impact morale levels. RWers estimated the changes in level of morale for when they were hired, when they would get promoted and when they would lose interest in their job. The changes in morale due to changes in health levels were also noted and also changes that would be expected if JRWDFTers were on flexitime. We also incorporated the changes in morale levels from support offered by the firm's life coach. The variables and factors were modelled around a normal distribution.

With regards to stress levels, the steady state was estimated to be 60%. RWers noted the changes in level of stress levels for varying levels of percentage work capacity, where work capacity is a measure of JRWDFT draft rate/ JRWDFT Normal DR (for JRWDFTers), that is to say how much RWers are working above or below their capable draft rate as demonstrated in the figure below (Figure 3.18).

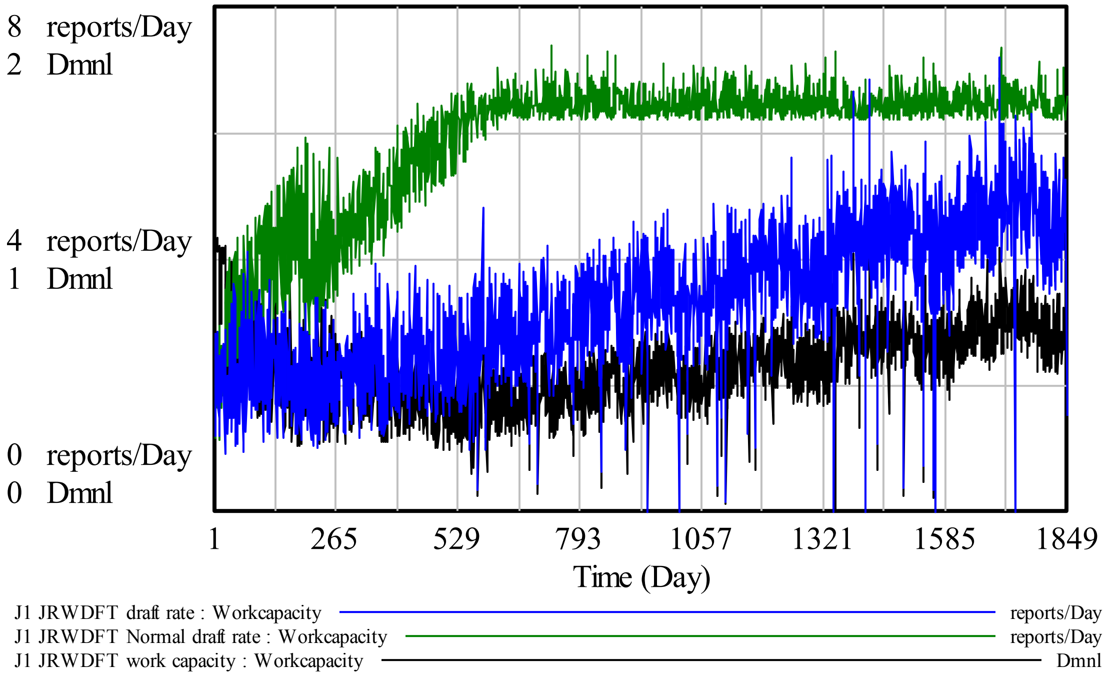


Figure 3.18: J1 JRWDFT work capacity

Figure 3.18 shows work capacity, initially at around 1 (100%), decreasing to roughly below 0.5 (50%) and staying there up until end of year 3 (day 792). J1 JRWDFT work capacity increases steadily from 0.5 (50%) from year 4 (day 793) to roughly 0.75 (75%) by the end of year 7 (day 1849). As the observed draft rate (J1 JRWDFT draft rate) increases slower than the anticipated growth in draft rate (J1 JRWDFT Normal draft rate) the work capacity decreases. As J1 JRWDFT Normal draft rate reaches its plateau and J1 JRWDFT draft rate increases with increasing firm task rate, J1 JRWDFT work capacity increases.

In a similar way we noted the changes in stress levels due to support, leisure time (how much leisure time RWers spend each day on average), job stress, which is a measure of job stress that comes with getting hired, getting a promotion and getting to a point of losing interest in the job, as well changes in stress levels due to the urgency of reports. The variables and factors were modelled around a normal distribution.

When looking at quality of work of JRWDFTers, the factors affecting productivity were noted as stress, morale and subjectivity. Their impact on quality was noted in accordance to responses from JRWDFTers. Subjectivity is the measure given for the subjectivity in grading of reports by SRWCHKers, where generally SRWCHKers may not deduct marks for JRWers who made a very rare mistake and may deduct a larger mark for JRWDFTers who continuously make the same mistakes. The qualitative variables, factors affecting them and the distributions used to model these are noted in Appendix D.

We now take a look at other underlying variables affecting qualitative variables. As Figure 3.8 showed, overtime and work capacity have an effect on support and leisure time. When RWers are required to work overtime, it is assumed that they do not have enough time to receive support and the effect of leisure is negligible. The same goes for when RWers work capacity is at 100% or higher. This means that all effort is being put in reports and therefore it is assumed that there is no time for support and the effect of leisure is negligible.

Modelling qualitative variables sees numerous inter-relationships and structures that see qualitative variables directly and indirectly affecting other qualitative variables. Changes in productivity due to qualitative variables also affect qualitative variables via direct and indirect loop. As such, a complex dynamic is formed between qualitative variables, as well as between qualitative and quantitative variables in the model. Variables such as training of RWers, salary, qualifications, client interaction were considered to have some effect on qualitative variables. However, we were careful not to model for variables that measured similar effects (double counting), modelling for variables that do not significantly affect productivity through qualitative variables and variables that may be too sensitive for RWers to give information or data about.

Below in Equation 3.1 to Equation 3.3, we highlight some of the dynamics behind feedback loops brought about by inter-relationships between qualitative variables and quantitative variable, with illustrations for changes in levels of stress, health and morale respectively. The equations illustrate how the feedback loops could potentially, as well as unpredictably, impact the behaviour of the business process. The significance of the impact that feedback loops have on the behaviour of the process shall become evident when we run model simulations for the objectives (Chapter 5).

Note for Equation 3.1 below: Work capacity and its interaction with stress can result in either a positive or negative effect on RWer productivity as follows:

Increase firm task rate → increase in productivity → increase in work capacity → increase in positive multiplier effect of work capacity on stress → increase in stress[1] → positive multiplier effect of stress on productivity[2] → increase in productivity

[1] Assuming work capacity is above 100%, and therefore increasing stress levels (Appendix D - JRWDFTer DATA collection Stress).

[2] Assuming stress levels increase to within the range of 60% to 80%, and therefore increasing productivity levels through stress (Figure 3.16).

ALTERNATIVELY

Increase firm task rate → increase in productivity → increase in work capacity[3] → decrease in support levels → decrease in multiplier effect of support on stress → increase in stress → negative multiplier effect of stress on productivity[4] → decrease in productivity

[3] Assuming that firm task rate is at such a level that RWers are forced to work beyond 100% work capacity.

Note: Increase in work capacity beyond 100% means that RWers are no longer able to receive stress support.

[4] Assuming stress levels increase towards 100%, and therefore decreasing productivity levels through stress (Figure 3.16).

Note: The increase in work capacity beyond 100% also adversely affects morale through the multiplier effect of support on morale. This results in a further negative impact on stress through the multiplier effect of morale on stress.

Equation 3.1:Work capacity feedback loop on stress

Note for Equation 3.2 below: Overtime and work capacity are seen to directly and indirectly adversely affect health levels respectively. The link between overtime and health is formed via the multiplier effect of overtime on health. Work capacity affects health through its link with stress, where increasing work capacity levels increases stress, which leads to stress affecting health through the multiplier effect of stress on health:

Increase firm task rate → increase in productivity → increase in overtime[1] → negative multiplier effect of overtime on health → decrease in health → negative multiplier effect of health on productivity → decrease in productivity

[1] Assuming that firm task rate is at such a level that RWers are forced to work overtime.

AND

Increase firm task rate → increase in productivity → increase in work capacity[2] → negative multiplier effect of work capacity on stress → increase in stress[3] → negative multiplier effect of stress on health → decrease in health → negative multiplier effect of health on productivity → decrease in productivity

[2] Assuming that firm task rate is at such a level that RWers are forced to work beyond 100% work capacity.

Note: Increase in work capacity beyond 100% means that RWers are no longer able to receive stress support.

[3] Assuming stress levels increase towards 100%, and therefore decreasing health levels through stress.

Equation 3.2: Overtime and Stress feedback loop on Health

Note for Equation 3.3 below: Increase in overtime and its interaction with health can result in either a negative or positive effect on Morale levels, and therefore positively or negatively affect RWer productivity, as follows:

Increase firm task rate → increase in productivity → increase in overtime[1] → negative multiplier effect of overtime on health → decrease in health → negative multiplier effect of health on morale → decrease in morale → negative multiplier effect of morale on productivity → decrease in productivity

[1] Assuming that firm task rate is at such a level that RWers are forced to work overtime.

ALTERNATIVELY

Increase firm task rate → increase in productivity → increase in overtime[2] → increase in productivity through multiplier effect of overtime on productivity[3] → increase in productivity → no overtime[4] → decrease in negative multiplier effect of overtime on health → increase in health → positive multiplier effect of health on morale → increase in morale → positive multiplier effect of morale on productivity → increase in productivity

[2] Assuming that firm task rate is at such a level that RWers are forced to work overtime.

[3] Increase in productivity because RWers are now working more hours.

[4] RWer productivity is now at point where overtime is no longer required.

Equation 3.3: Overtime and health feedback loop on Morale

Key Note: The changes in the levels of key variables that potentially bring about changes in the direction of feedback loops at each point in time add to the complex dynamics behind the business process.

The feedback loops illustrated above show how changes in qualitative variables brought about by the loops are not always predictable, with the level of change of the variables also potentially unpredictable. The qualitative variables are said to be linked to RWer productivity through their respective multiplier effect on productivity, which essentially means that the behaviour of the process over time is potentially unpredictable given the various dynamic changes in the level of qualitative variables brought about by feedback loops.

Examples of other loops, which were picked up using the Vensim simulation software, are set out in Appendix E, with some of relatively great length (+30 in length). The significance of the impact that the feedback structures have on the behaviour of the process shall become evident when we run model simulations for the objectives (Chapter 5).

Data Collection – Cognitive Mapping

Part of the model development involved the use of cognitive mapping to evaluate management's strategic view of the business. The cognitive map helps us to identify key areas in the business process based on management's goals and aspirations (Eden, 2004).

In our context of studying a business process, the concept of cognitive mapping looks into garnering management's perspective of the process as they have experienced it over a period of time (Eden, 2004) and translating these into a map (Bryson, et al., 2004). A cognitive mapping interview session was organised with the vice president of the firm with the rest of management later confirming that the map drawn out by the vice president strongly reflected their own perspective. Below we summarise the steps taken to develop the cognitive map. Appendix D, under the heading "Stages in building cognitive map", has the comprehensive steps taken to build the map.

Stages in building cognitive map:

1. Research on literature on cognitive mapping and its usefulness in aiding simulation modelling.
2. Aligning the usefulness of cognitive mapping to the research case study.
3. Setting out the questions for the cognitive mapping session.
4. Sending out email request to management to conduct cognitive mapping sessions with each of them (director, president and vice president).
5. Meeting confirmation from vice president. Meeting declined from director and president due to time constraints.
6. The first cognitive mapping session with the vice president.
7. Follow up cognitive mapping session with the vice president.
8. Translation of transcripts from the cognitive mapping session into the cognitive map with the aid of the vice president.

Below is the cognitive map that was drawn up. The map, as well as the written responses was forwarded to the rest of management via email, and they responded to say that they were happy with the map and had nothing new to add. It is possible that not much time was taken by the rest of management (president and director) to go over the responses and cognitive map, which could possibly mean that the cognitive mapping is heavily biased towards the perspective of the vice president. The data and information obtained to build the cognitive map would have been relatively more reliable and unbiased had the writer had the chance to hold a session with each of the senior managers.

At the time of finalising the cognitive map, we had learned more about the firm in terms of why and how it was established. We also had an understanding of the problems and concerns the firm previously faced and currently faces, as well as those it expects to face. We had a sense of the firm's business model, learning how the firm has grown over the years and how management sees it growing in the near future. Below on page 77 are some of the key findings gained. In chapter 4 we outline each objective. The sub headings *General Background* and *Objectives set out* under each objective in that chapter are based strongly on key findings from the cognitive mapping. This helped with setting out clear objectives, based on issues that management had a real interest in understanding.

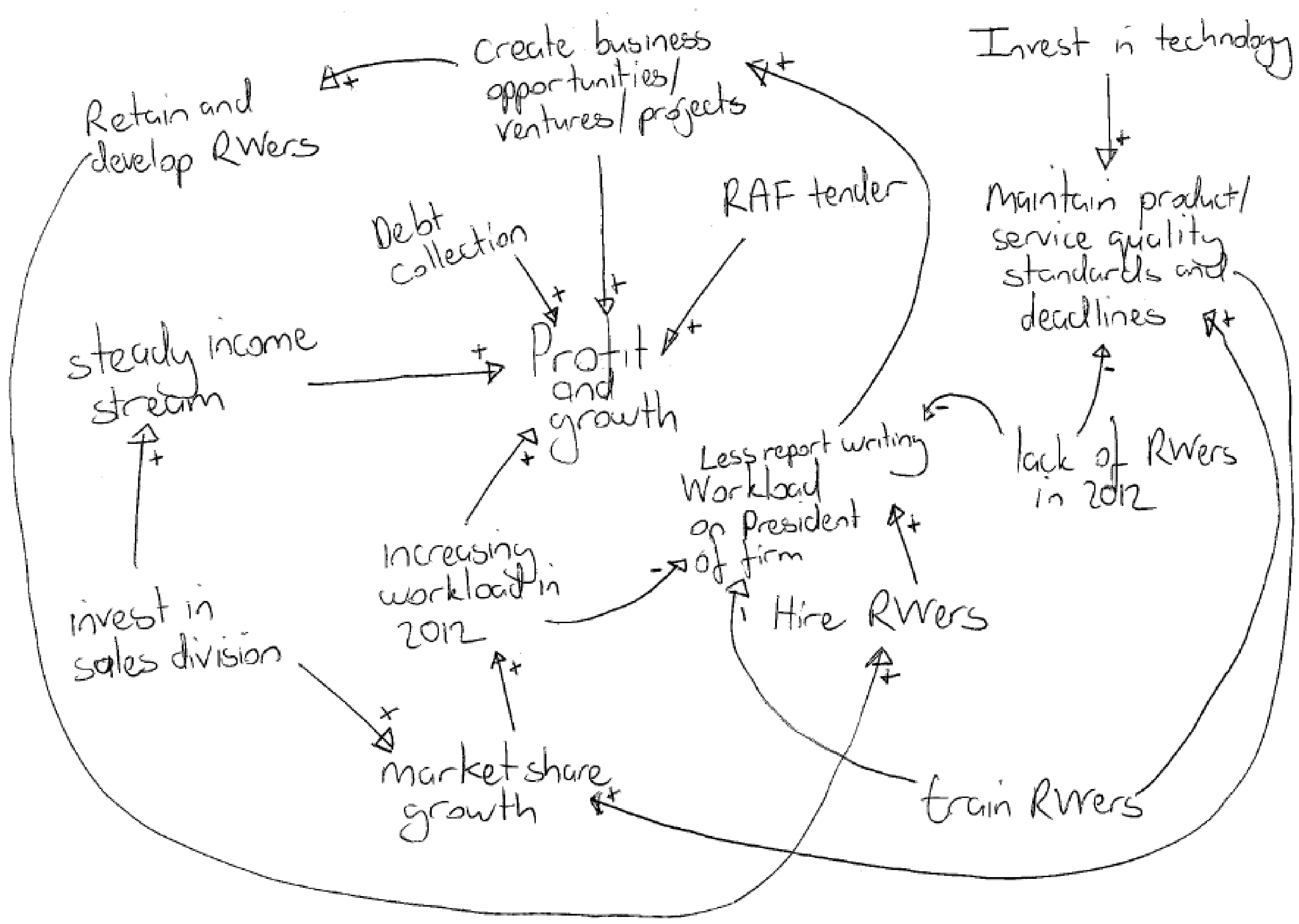


Figure 3.19: Management’s cognitive map

Looking at the resulting conversation with the vice president and drawing up an initial map, we were able to see that the main focus of the firm is to grow the business and its income stream. This would be done via different channels, for example, increasing market share, better debt collection, invest in sales team, to name a few. But concurrently the firm must look into increasing capacity to maintain and sustain expected growth. A strong interaction was noted between business growth and recruitment/ retention/ personal development of RWers, with business growth being dependent on sustaining a certain level of capacity growth and sustaining a certain level of capacity growth being dependent on business growth and opportunities.

Below we summarise the key findings from the cognitive mapping session:

- The need for business growth and income stream dependent on capturing market share and viable business venture.
- The expected increase in workload results in the firm's necessity to hire RWers to maintain quality and deadlines.
- Cash flow constraints act as hindrance to hiring RWers prior to the firm stabilising financially.
- There is a need for business growth in order to motivate and retain RWers.
- There is concern over uncertainty around the quantity of work that the firm is expected receive from the RAF.
- There is a need to find new avenues for income and business, diversifying away from RAF work.
- There is a need for constantly improving administrative technology given the expected increasing workload and need to maintain quality of work and meet deadlines.

The findings above from the cognitive mapping assist us to be more specific with the objectives, which are set out in the next chapter. For example, with regards to modelling the firm's future growth path, we are able to establish key areas of concern that the firm would like to investigate. The model will seek to evaluate the impact of future expected workload on productivity given future expected capacity, given the uncertainty around workload due to the new RAF rotation system. The combination of a possible increase in workload and the possibility of the firm branching out into a different venture means that the research should also give us insight into how many RWers are required during our period of analysis.

What was interesting to note was that management knew the importance of employee retention in the future, as the firm grows in capacity and workload, and highlighted the importance of motivating RWers and creating growth opportunities for RWers.

The use of cognitive mapping in our context is seen as a useful tool in setting out objectives that are clear given the background knowledge about the firm and its business process as captured in the cognitive map. This then allows us to build specific models that are aligned to the clear objectives.

3.5 Data and Information Verification

We have already mentioned some of the challenges of collecting data and information when it came to building the cognitive mapping. This included the challenge of conducting a cognitive mapping session where the writer had to ask the questions, listen to the responses, as well as jot them down. It may have been easier for the writer to record the session, and then after the session play back the recording and jot down the answers and key findings. However, the vice president was willing to repeat and elaborate answers, which was itself a useful process of clarification.

The reliability of the information collected from the cognitive mapping session with the vice president was verified by the rest of management. It cannot be said whether or not enough time was taken by the rest of management to actually go through all the responses given by the vice president and the eventual cognitive map that was drawn. Ideally, we would have wanted to have separate cognitive mapping sessions with each member of management, and cross referenced the information gathered from each session to build the cognitive map.

Generally, with regards to the data and information gathering, we only had the chance of having a few workshops and discussion sessions with RWers and management given the time constraints of RWers and management. The core of the workshops and discussion sessions were done during the relatively less busy first quarter of 2013. It was easier for the writer to hold sessions with the RWers as a group during this period. For example, we had the JRWers answer the questionnaires in one group session, and that was followed by a session where the SRWers answered the questionnaires. The questions in the questionnaire that asked about quantifying quantitative variables were relatively objective (Appendix D). Some of the fairly objective questions were as follows:

- *What was your initial productivity (reports/day and reports/week) during your probation period (i.e. first months on the job)?*
- *What is your current productivity (reports/day and reports/week)?*
- *How many months have you been employed at this firm?*

Where there could have been some biased data was with regards to quantifying qualitative variables. These sessions were characterised with a few RWers asking their peers what they had written down for their answers for questions like these:

- *As per our discussion, please estimate the % change in morale at (a) the beginning of your probation period (b) the beginning of a promotion (c) when you feel there is not more you can learn or develop from your job.*
- *As per our discussion, please estimate the % change in morale if you were allowed flexitime.*
- *As per our discussion, please estimate the % change in morale brought about by health being at the following levels...*

However, a study of the answers around qualitative variables showed that the responses differed (Appendix D). A better, but more time consuming, solution to gathering data and information would have been to hold individual sessions with each RWer, asking them to answer the questionnaires.

Due to time constraints, we set out to have a series of rounds of data and information gathering with each group, where the first rounds we would gather information from RWers through the use of questionnaires and information from management through a cognitive mapping session. During the course of the research we planned to repeat this step of information gathering at least twice in order to verify if the information provided is consistent given the information provided in the initial phases.

As we mentioned earlier about the cognitive mapping sessions, quite a few sessions were held with the vice president before the map was finalised. With regards to data and information from RWers, we did manage to get a second round of data and information gathering with regards to qualitative variables. What helped in corroborating the data and information gathered were the feedback sessions where the writer was able to present the models and findings to RWers and management, as this gave them a chance to voice their concerns around the model.

4. Objectives and Methodology

4.1 Overview

The overall objective of our research is to model, better understand and evaluate the firm's business process. This chapter focuses on outlining the five objectives discussed in Chapter 1 and give a step-by-step methodology as to how we shall tackle each of the set objectives. Each objective makes use of models generated using Vensim simulation software.

4.2 Objective: Analysis of Qualitative Variables

General Background

When we talk about an employee's general well-being in our research, we refer to their level of stress, morale and health at work, as defined in Chapter 3. The general well-being of an employee is vital to the firm, as it affects the employee's overall productivity. Generally, it has been seen that employees who are happier and healthier at work are less likely to be absent from work, call in sick or quit their jobs, resulting in a loss in productivity (Halpern, 2005). Happier and healthier employees are more likely to work harder, be more focused and engaged on the job at hand and therefore are generally more productive than those who are not (Halpern, 2005). It may then be in the interest of the firm for management to invest in employee well-being. One of the ways management can go about this is by determining the key qualitative variables affecting employee productivity, as well as investigating what variables could bring about change in the level of these qualitative variables. We are interested in investigating the impact of the three key qualitative variables described in Chapter 3 (health, morale and stress) on RWer productivity. We also assess the impact that changes in the level of quality of work drafted by JRWDFTers (quality variable) has on their productivity.

Objective set out

Through model simulations, we want to investigate the impact that each qualitative variable has on productivity, assessing which qualitative variables have the greatest (least) impact on productivity. This objective gives us an idea of the key qualitative variables governing RWer productivity.

Method Used

Our approach in establishing the impact each variable has on productivity is to gradually increase the level of one qualitative variable, all else constant, and assessing the impact the single variable has on productivity at these various levels. Table 4.1 lays out the model runs we wish utilize to establish the significance that each variable has on a RWer's productivity. Here we use a seven year period of analysis.

Scenario	Qualitative variable level
Sce. 1	0%
Sce. 2	20%
Sce. 3	40%
Sce. 4	60%
Sce. 5	80%
Sce. 6	100%

Table 4.1: Analysing Effect of Qualitative Variables with Increasing Levels

4.3 Objective: Initial Hiring of Report Writers

General Background

As highlighted earlier, one of the major reasons why the firm is doing so well financially and keeps growing in client-base is due to its excellent service of delivering reports to the client within 48 hours or sooner, depending on how urgently the client may need the report. In order to maintain this commitment to clients the firm needs to be adequately staffed at all times.

During its initial exponential growth phase, it became important for the firm to hire more RWers as the capacity at that time would not have managed the rapidly increasing workload. The idea of hiring an adequate number of RWers required substantial capital on hand to pay their salaries. However, it must be pointed out that the nature of the business is such that clients generally only pay for the firm's services after matters have been settled, with some matters taking up to two years to settle. So the initial hiring of RWers at the stage where the firm's workload was now rapidly growing was going to prove challenging for the firm given its financial constraints. At the same time the firm had to worry about hiring enough people with actuarial backgrounds to ensure that should other actuarial opportunities arise they had the right personnel to administer them.

In order to solve these problems management chose to hire non-actuarial recruits (JRWDFTers) with a strong quantitative background that would hopefully progress to JRWSNDers and send their own reports. This would allow SRWCHKers to move out of the report writing area and into other actuarial opportunities within the company once these opportunities had materialised.

The option of hiring JRWDFTers was seen as a more feasible option with regards to salaries paid to JRWDFTers, but would require more time spent training these recruits in actuarial matters and progressing them to a stage where they can send their own reports. Given the firm's financial constraint at the time and their desperate need for RWers, management went with the option of initially hiring non-actuarial RWers (JRWDFTers). Salary costs were covered, deadlines were met and management kept in mind the prospects of getting SRWCHKers involved in other actuarial opportunities in the future.

The decision to hire more RWers at the beginning of 2012 was mainly as a result of an increase in flow of client work in the months prior to the beginning of 2012 and its expected continued increase in the future. There was a need to establish a right number of RWers to hire at this stage.

Objective set out

We wish to evaluate the firm's productivity given different scenarios where the firm initially hires ***x*** number of SRWCHKers for every 2***x*** number of JRWDFTers hired. The assumption made by management, and reinforced by data (Appendix D) is that a SRWCHKers, on average, take half as long to check a report as the time it takes to be drafted by a JRWDFTers. This basically says that if two JRWDFTers draft one report each in one hour then it will take a SRWCHKer one hour in total to check the two reports (30 minutes for each report).

Establish value of *x*. What we set out to do is investigate what value of x is needed to manage the increasing workload simulated for year 1 to end of year 3. At the end of year 3 JRWDFTers are expected to be able to send their own reports and hence the checking phase phases out by then. This value of x must be such that minimal deadlines are missed, overtime is mitigated and enough cover is there should there be an unexpected influx of reports or should a few RWers not be available to work. We also take note of the work capacity of RWers created by having a certain number of RWers.

Method Used

Table 4.2 shows the different values of x we wish to run simulations for.

Model Run	Number of JRWDFTers (2x)	Number of SRWCHKers (x)
Sce. 1	2	1
Sce. 2	4	2
Sce. 3	6	3
Sce. 4	8	4
Sce. 5	10	5
Sce. 6	12	6
Sce. 7	14	7

Table 4.2: Outline Approach of Exploration of Initial Hiring Phase

4.4 Objective: Allocation of Report Writers

General Background

There have been two major RWer roles at the company thus far. The one role sees JRWDFTers drafting reports only. The other role sees SRWCHKers only checking reports drafted by JRWDFTers. Two other roles are also possible, namely JRWSNDers and SRWSNDers, which see JRWers and SRWers respectively, sending off their own reports. Of interest is exploring how to allocate RWers into the different roles mentioned and what effect the different allocations would have on the business process in terms of productivity.

Objective set out

Through the use of our business process model, we wish to evaluate what the quantitative and qualitative differences are of allocating RWers to specific roles, namely as follows:

- Scenario 1 - JRWDFTers and SRWCHKers only
- Scenario 2 - JRWSNDers and SRWSNDers only
- Scenario 3 - Combination of JRWDFTers, SRWCHKers, JRWSNDers and SRWSNDers

Method Used

In our analysis of the different roles that RWers can take on, we take the number of RWers determined by the value of x that will be established in section 5.2 of the results section and use it to explore the scenario set out in our objective above. Table 4.3 illustrates the scenarios we wish to explore under the hypothetical assumption that the ideal value of x is 5. 200 simulations will be run for this analysis. The analysis is done from the beginning of year 4, when it is assumed that all JRWDFTers are capable of being JRWSNDers, until the end of year 7.

Scenario	Type of RWer	RWer role	Number of RWers
Sce. 1	JRWDFTers	Draft only	10
	SRWCHKers	Check only	5
Sce. 2	JRWSNDers	Draft & Send	10
	SRWSNDers	Draft & Send	5
Sce. 3	JRWDFTers	Draft only	5
	SRWCHKers	Check only	3
	JRWSNDers	Draft & Send	5
	SRWSNDers	Draft & Send	2

Table 4.3: Outline Approach of Exploration of Allocation of RWers

In terms of objectives and results, from this objective going forward, we assume that the firm has adopted Scenario 2 from the beginning of year 4. From our cognitive mapping session it was clear that management intends to progress JRWDFTers to JRWSNDers after at least 3 years, giving JRWers a new challenge. What was also clear was that at some point management intends for SRWers to take on new actuarial opportunities outside of reporting, doing this without compromising on resources required to do reports.

4.5 Objective: Turnover of Report Writers

General Background

It is generally known that almost all firms go through a turnover of employees at some stage of their existence. Looking at the firm, one of the primary concerns around RWer turnover is the rate of turnover of the RWers. Another concern is adequately replacing the RWers who leave the firm, especially experienced RWers who are of great value to the firm. It is then in management's best interest to investigate the potential dangers of losing employees at any given point in time and assessing how much of an impact that a high turnover has on the firm's productivity even if they are replaced.

Objective set out

In this section, we explore the consequences of having a firm with a high turnover rate. In this case the firm continuously starts losing RWer with at least 3 years of experience at any point in time after 3 years. Their replacements take time to be recruited as the firm looks for replacements. The replacements for the RWers have varying skills set; specifically they are subject to drastic changes in health, morale or stress levels.

Method Used

200 simulations will be run for this period of analysis from year 4. Our assumption, from the beginning of year 4, is that individual JRWSNDers quit the firm within two weeks to a year and that it takes anything between two weeks to a year to replace them. For individual SRWSNDers it takes them anything between a month to two years to quit and it takes a similar period of time to replace them. Each replacement is seen to have fluctuating levels of either health, morale or stress levels, with the levels fluctuating between 0% and 100% each month with equal probability. This model will be compared to a model where the RWers are replaced with recruits that are equally as skilled as them. Our analysis will look at the impact that the continuous turnover of relatively stable RWers with relatively unstable RWers will have on productivity and other key performance indicators.

4.6 Objective: Introduction of Flexitime

General Background

Flexitime describes the concept behind the flexible working arrangement for employees at a firm. In most cases an ideal flexitime arrangement would result in an increase in employee productivity and better work environment. In our instance, we described flexitime as time out of office that RWers, specifically JRWSNDers, take to do other work-related projects outside of report writing.

Objective set out

By exploring the concept of flexitime we are hoping to discover the direct and indirect benefits of the arrangement to the firm. Our interests specifically lie within exploring the boost in morale that comes with working under such an arrangement and how it could possibly improve work capacity.

Method Used

Our assessment will compare two models; one which does not allow for flexitime and one that allows for it. We then wish to compare the differences in productivity and other key performance indicators from these models and simulations. The model that allows flexitime assumes that there is a 50% chance that management will agree for individual JRWSNDers to go on flexitime on any given day during the period of analysis. For this analysis, 200 simulations will be run for the period between year 4 and year 7 inclusive.

In tackling the objectives, we also wish to determine the significance of the impact that relevant feedback loops have on the behaviour of the process.

5. Analysis of Results

5.1 Overview

We now take a look at the results obtained from our model simulations from each of our five objectives set out. The models are run for a period of 7 years, our period of analysis, and the results are based on a 95% confidence interval with 200 simulations being run for each model, unless stated otherwise.

We shall run model simulations for each objective, assessing the general results obtained from the model simulations. Once we have established the significance of qualitative variables in section 5.2, we shall run simulations for each of the set objectives, identifying key findings, as well as the role that key variables and inter-relationships, including feedback loops, play in determining the behaviour of the business process.

5.2 Analysis of Qualitative Variables

It took the writer two attempts to model for qualitative variables with the first attempt leading to the writer reaching conclusions that suggested that qualitative variables have no significant impact on productivity. The results suggested that the productivity at optimal levels of health, morale, stress or quality levels are comparable with productivity at extremely adverse levels of health, morale, stress or quality. These worrisome results led to the writer going back to the models to pick up the reason why these results were comparable. The results obtained and re-modelling done are discussed in the section 5.2.1 below.

This first attempt at modelling qualitative variables is discussed in this paper because it highlights a key aspect of system dynamic modelling where modellers often have to re-model models after obtaining peculiar results (Akkermans, 1995). The presentation of the peculiar results to stakeholders may also lead to new perspectives bring brought forward and incorporated into the revised models. This was the case for the writer as discussed below.

5.2.1 First Attempt at Modelling Qualitative Variables

To highlight the significance of the impact of qualitative variables on productivity we took each qualitative variable and increased its level by 20% from 0% to 100% all else constant. Our objective is to determine how much of an impact changing the levels of each qualitative variable has on productivity.

The first attempt at modelling qualitative variables led us to the following conclusions about qualitative variables as highlighted in Table 5.1 below.

Scenario	S0	S1	S2	S3	S4	S5
HEALTH LEVEL	0%	20%	40%	60%	80%	100%
JRW (reports/Day)	0.00	0.75	0.75	0.77	0.77	0.77
SRW (reports/Day)	0.00	0.70	0.70	0.70	0.70	0.70
Scenario	S0	S1	S2	S3	S4	S5
MORALE LEVEL	0%	20%	40%	60%	80%	100%
JRW (reports/Day)	0.00	0.73	0.74	0.77	0.77	0.77
SRW (reports/Day)	0.00	0.65	0.70	0.70	0.70	0.70
Scenario	S0	S1	S2	S3	S4	S5
STRESS LEVEL	0%	20%	40%	60%	80%	100%
JRW (reports/Day)	0.00	0.77	0.77	0.77	0.75	0.75
SRW (reports/Day)	0.00	0.69	0.69	0.70	0.70	0.70
Scenario	S0	S1	S2	S3	S4	S5
QUALITY LEVEL	0%	20%	40%	60%	80%	100%
JRW (reports/Day)	0.00	0.71	0.73	0.75	0.77	0.77

Table 5.1: Marginal increase in reports per day due to increasing levels in qualitative variables

For JRWDFTers and SRWCHKers the results showed that there is a positive relationship between increasing levels of qualitative variables and marginal productivity, where marginal productivity, in this cases, was measured as an increase in the number of reports per day. Already the results were suggesting that productivity could be increased at low levels of health, morale and quality. There was no negative influence brought about by qualitative variables even at extremely adverse levels.

The results also suggested that there was only a slight different, of less than a report a day, brought about by increasing qualitative levels from one extreme to the other. For example, health levels of 0% resulted in no change to productivity, whilst increasing health to 100% meant productivity increased by 0.77 of a report per day. The results were mainly due to the way that the writer posed the questionnaire around the data collection of qualitative variables. The first attempt at modelling qualitative variables was initially done as follow, with the illustration for health levels impact on productivity.

*When Health is at x%, I draft/check y reports **more** than normal.*

Morale (x %)	Draft/Check Rate (y reports/day)
0	
20	
40	
60	
80	
100	

The questionnaire handed to the RWers lead them to fill out zero (0) more reports than normal for all qualitative variables at the 0% level. Although it would have been possible for them to state that they drafted minus y reports a day at extreme levels, the fact that the questionnaire was phrased as "I draft/check y reports **more** than normal" lead them to believe that the y had to be zero or positive.

The questionnaire was then changed in such a way that RWers had to state the percentage change in y brought about by changes in x, as discussed in Chapter 3. The time between the first and second round of discussions and questionnaires was about 3 months. The time period between the two lead to RWers gaining more perspective about qualitative variables and their impact on productivity.

By the end of the second round of discussions and questionnaires some of the variables that were said to impact qualitative variables were altered and more were incorporated as RWers believed that the variables listed better reflected the impact of variables on qualitative variables. For example, the multiplier to morale due to job satisfaction (MTmDTjobsat) was altered from general job satisfaction over the period of analysis to job satisfaction linked to RWers' probation period, promotions and job saturation. We now discuss the results obtained from the revised models.

5.2.2 Analysis of Qualitative Variables

Our analysis of results again starts with us analysing the qualitative variables used in the models. As a recap, our main qualitative variables are health, morale and stress. This section will see as exploring the impact that changing levels of qualitative variables has on productivity. As a reminder, the multiplier to productivity due to health or morale or stress or quality is the marginal increase or decrease in productivity due to an increase or decrease in the level of health or morale or stress or quality respectively.

We first start by observing the trend of individual JRWers' and SRWers' productivity, their qualitative levels, and their multipliers over time respectively. Our model in this chapter is run with 10 JRWDFTers and 5 SRWCHKers over the entire period of analysis of 7 years. The number of RWers is based on our analysis on the initial hiring of RWers (objective 2).

To give this chapter a bit of context we begin by illustrating the firm's productivity, total JRWDFTer and total SRWCHKer productivity over time. The figure illustrating their productivity is shown below (Figure 5.2). Here we see that the firm productivity more or less matches firm task rate. In this analysis, we analyse individual JRWDFTers and SRWCHKers as opposed to the whole firm. The reason for this individual analysis is so that we can analyse the impact of qualitative variables on the individual's productivity by changing the levels of the qualitative variables whilst ensuring that the firm is still able to function over time. The individual J1 JRWDFT and S1 SRWCHK qualitative variable levels are illustrated in Figure 5.2 to Figure 5.4 below. These figures illustrate their general levels of productivity, qualitative variables and multiplier effects.

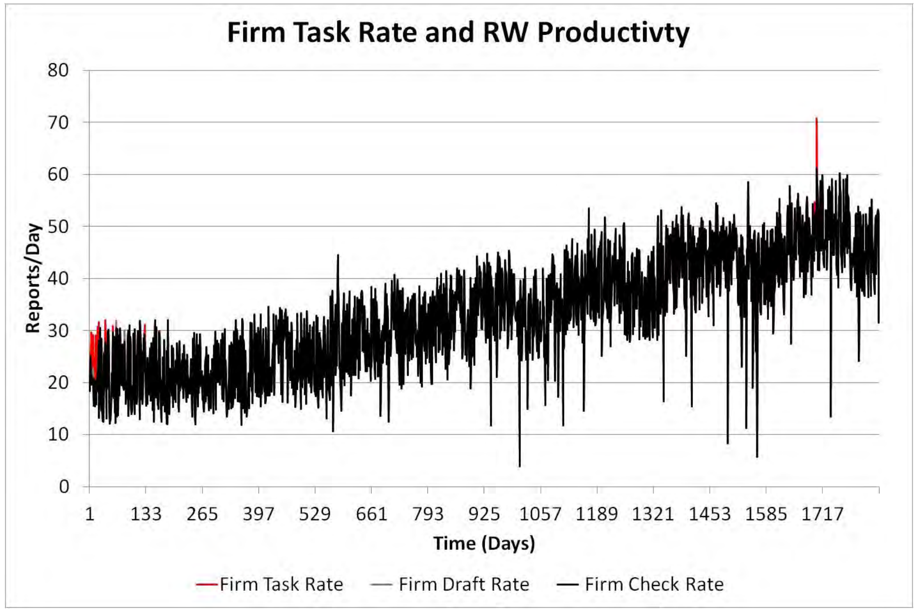


Figure 5.1: Firm Task Rate and RW Productivity

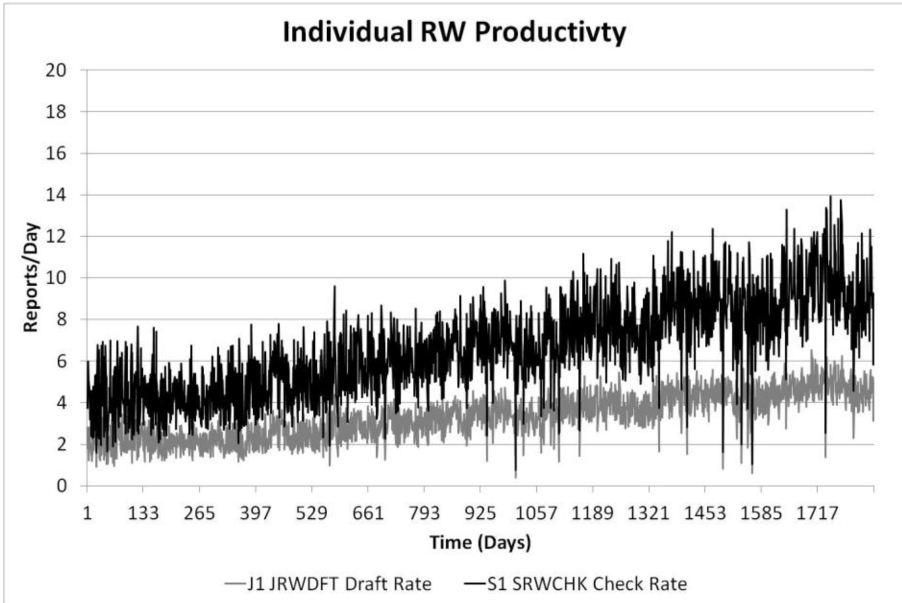


Figure 5.2: Individual RW Productivity

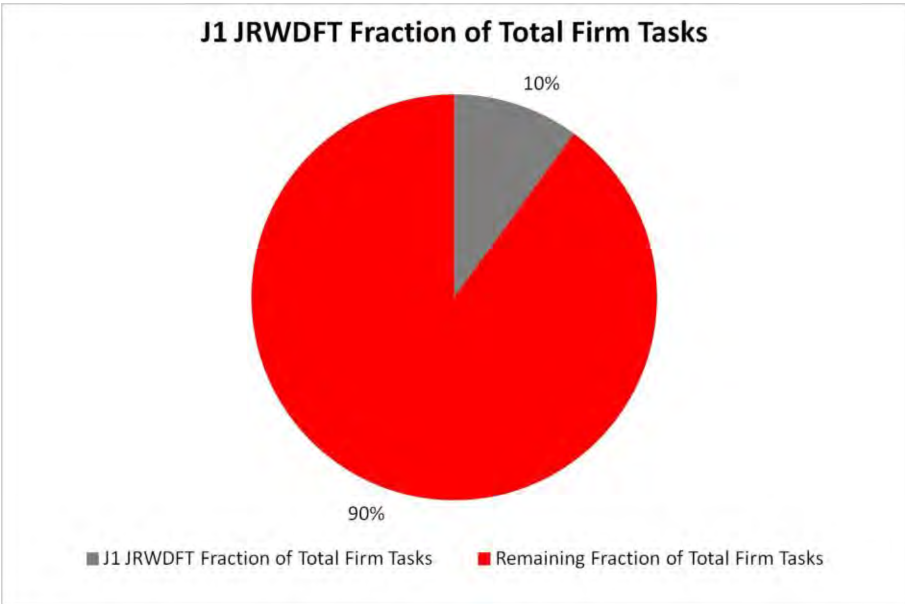


Figure 5.3: J1 JRWDFT Fraction of Total Firm Tasks

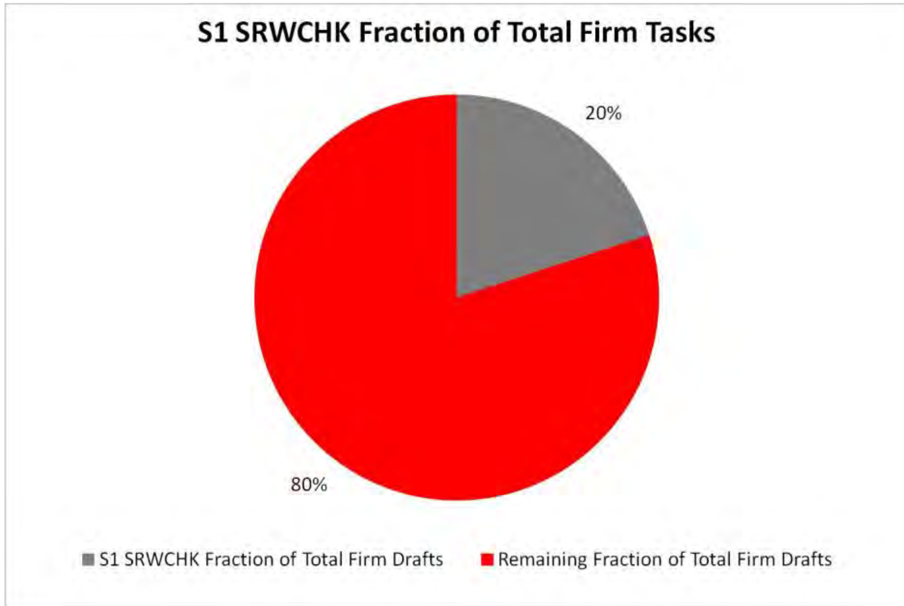


Figure 5.4: S1 SRWCHK Fraction of Total Firm Tasks

The firm task rate shows an increasing trajectory over time with a seasonal trend as shown in Figure 5.1. The growth reflects the expected growth of the firm's incoming work over time, whilst taking into account the 3 main seasons during each year, namely the quiet, normal and busy period. The large spikes seen across the years would be brought about by the unexpected influx of reports coming in or unexpected large drop in task rate. JRWDFTers and SRWSNDers closely match this task rate over time as illustrated in the diagram. On an individual level we see how much J1 JRWDFT and S1 SRWCHK add to the firm's productivity in Figure 5.2, Figure 5.4: and Figure with tasks not drafted spread amongst 10 JRWDFTers and tasks not checked spread amongst 5 SRWCHKers.

We now look at the changes in qualitative variables levels over time for individual RWers. Our analysis of health levels shows a seasonal trend in the level of health over time as shown in Figure 5.5 to Figure 5.8. The trend is due to the impact of exhaustion on health levels over time with exhaustion levels changing in accordance to the different seasons of the year, namely the quiet, normal and busy period. Other influencing factors of health levels are percentage overtime worked, susceptibility to sickness and stress levels. The impact of each of these on health is discussed in more detail in Chapter 3. The drastic decline in health levels mainly come about at the end of the busy season, when exhaustion levels are highest, in the case where RWers have to work overtime and stress levels are marginally high.

What follows are figures relating to RWers morale. The changes in the level of morale levels over time illustrate the changes due to job promotion (initial spike in morale). Health levels also give morale a seasonal element to its trend. As experience (time) progresses, the RWers reach a stage of job saturation where morale levels begin to decline. Another upward spike is seen for J1 JRWDFT when he gets a promotion after roughly 3 years. Other influencing factors of morale levels are percentage support levels and flexitime (not applicable in this analysis) which are discussed in Chapter 3.

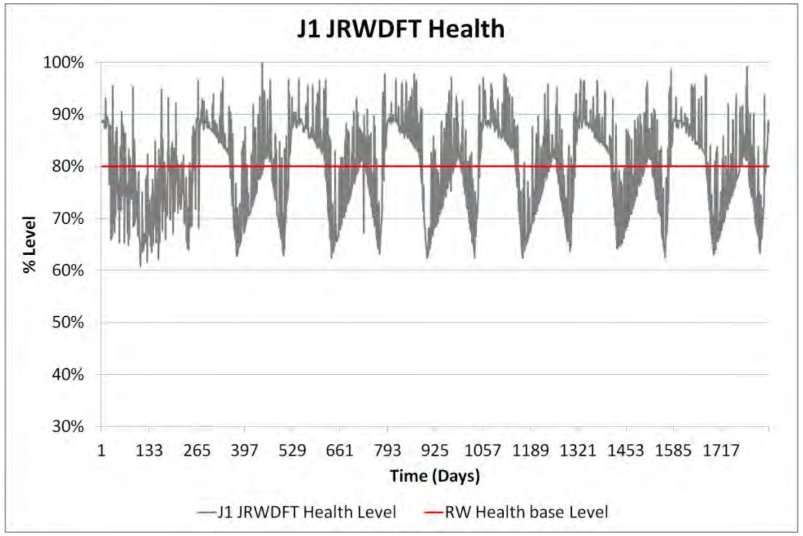


Figure 5.5: J1 JRWDFT Health Level

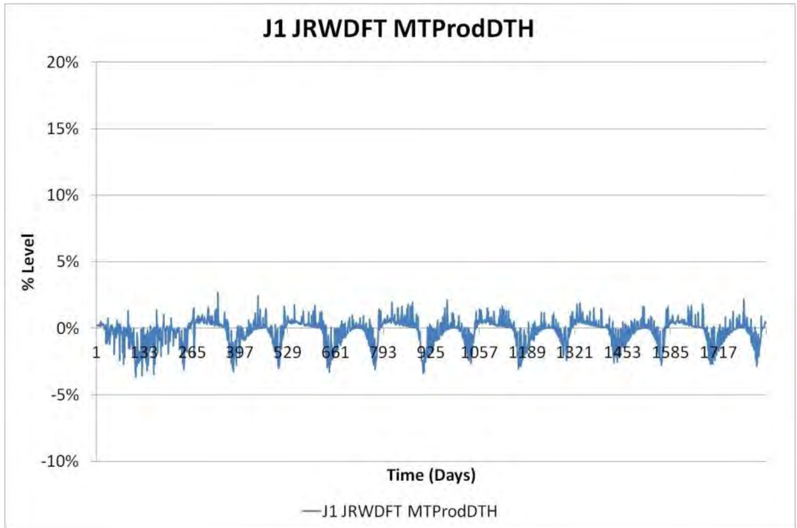


Figure 5.6: J1 JRWDFT MTProdDTH

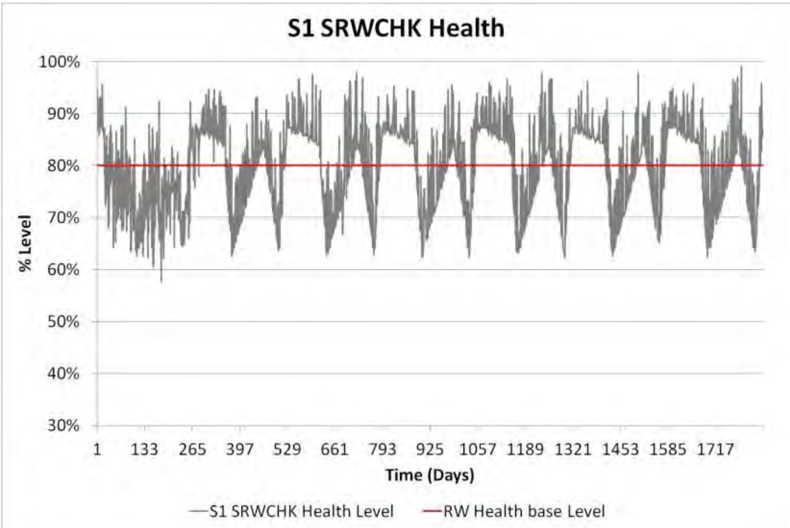


Figure 5.7: S1 SRWCHK Health Level

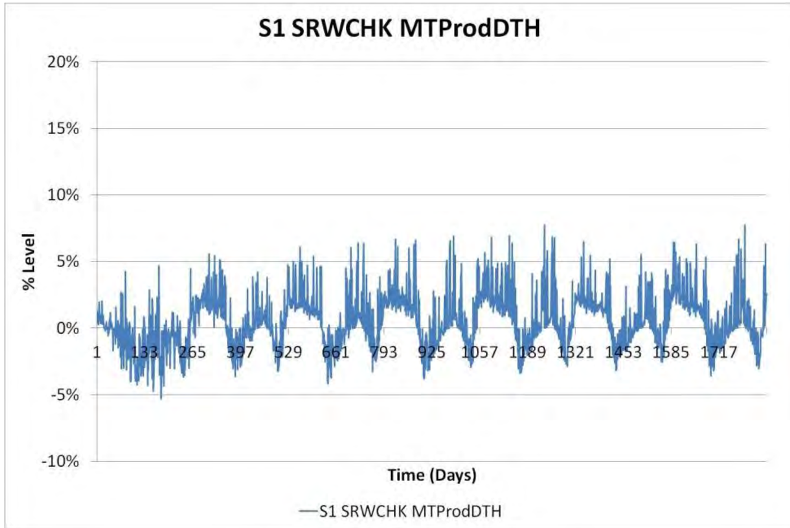


Figure 5.8: S1 SRWCHK MTProdDTH

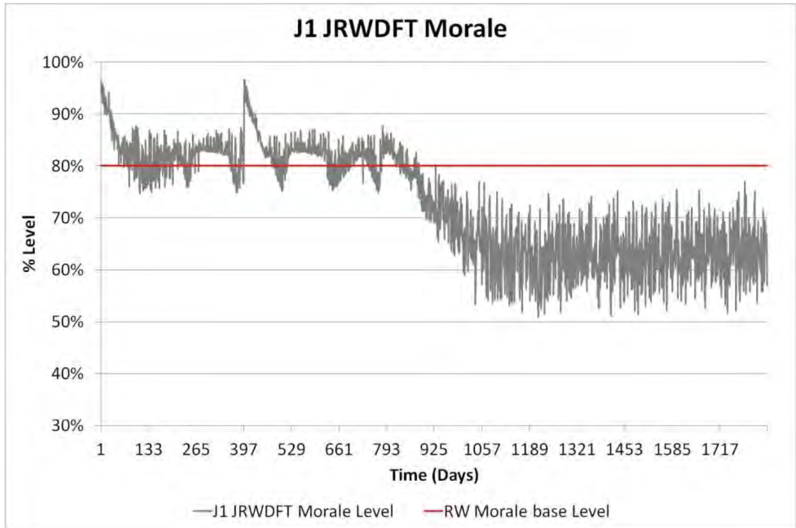


Figure 5.9: J1 JRWDFT Morale Level

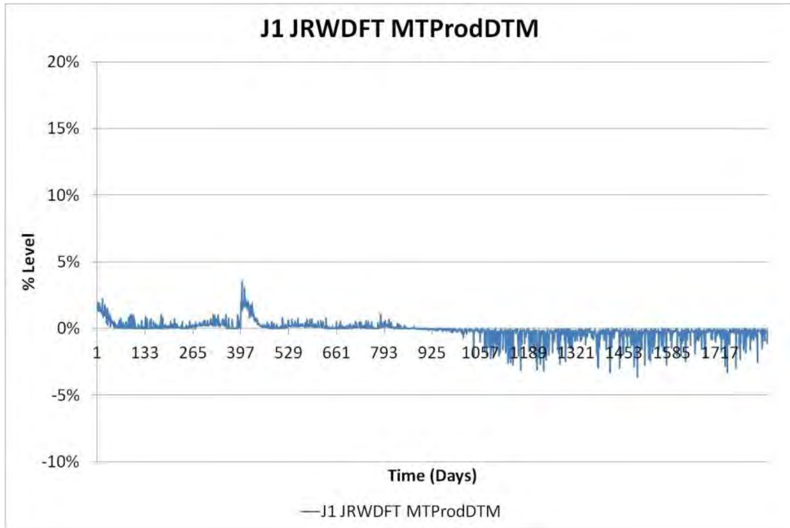


Figure 5.10: J1 JRWDFT MTProdDTM

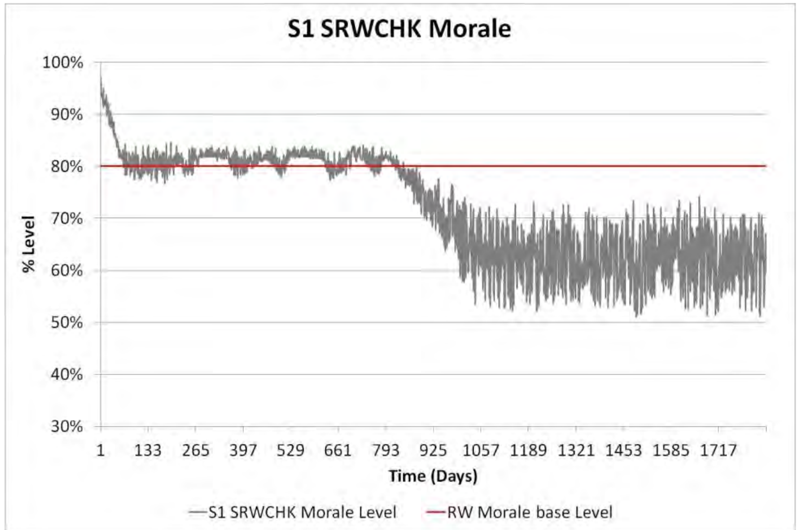


Figure 5.11: S1 SRWCHK Morale Level

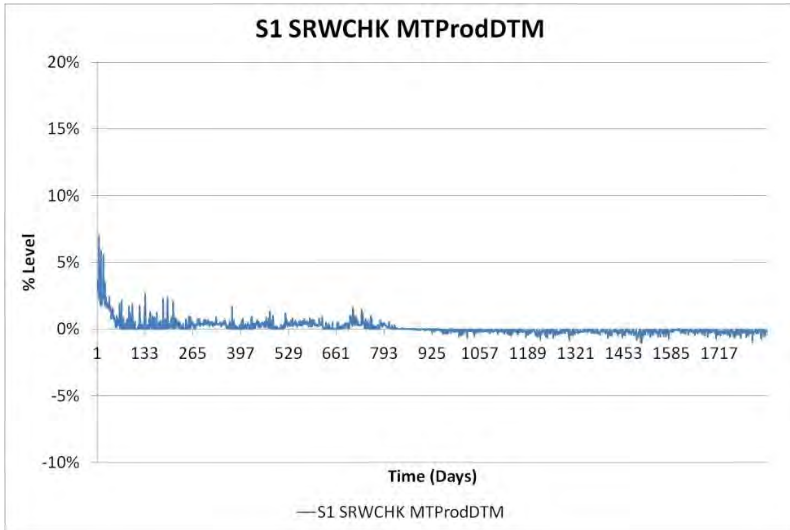


Figure 5.12: S1 SRWCHK MTProdDTM

The trend in stress levels is quite similar (Figure 5.13 and Figure 5.14) to that of morale, where an initial spike can be seen as RWers take on the responsibility of their new job. Initially as well, the stress levels are high as RWers are still adjusting to the work rate required of them. As experience increases, their work rate improves, which then decreases stress levels. Similarly for JRWDFTers and morale an upward spike in stress is seen for J1 JRWDFT when he gets a promotion due to more responsibility being taken on. Other influencing factors of stress are the percentage of reports that are said to be urgent, the level of support given to the RWers and the amount of leisure time they have which are all discussed in Chapter 3.

There is an upward trend in the level of quality of reports drafted by J1 JRWDFT as shown in Figure 5.18. With increasing experience, the quality levels increase and the variation decreases. At some stage, roughly after 3 years of experience, the quality level plateaus at 100%. The main variations in quality levels are caused by changes in morale levels and changes in stress levels. The influence of these variables declines with experience. The influence of experience, morale and stress on quality levels have been discussed in more detail in Chapter 3.

The trend we see with the multiplier effect of each qualitative variable on productivity is that as the level of the qualitative variable deviates from the base level, the multiplier effect increases, with large changes to the multiplier effect occurring the further away the qualitative levels are from their base levels.

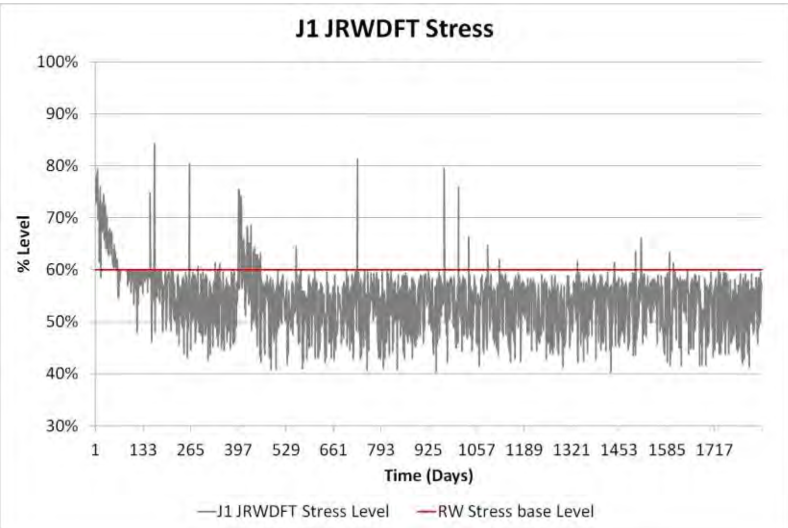


Figure 5.13: J1 JRWDFT Stress Level

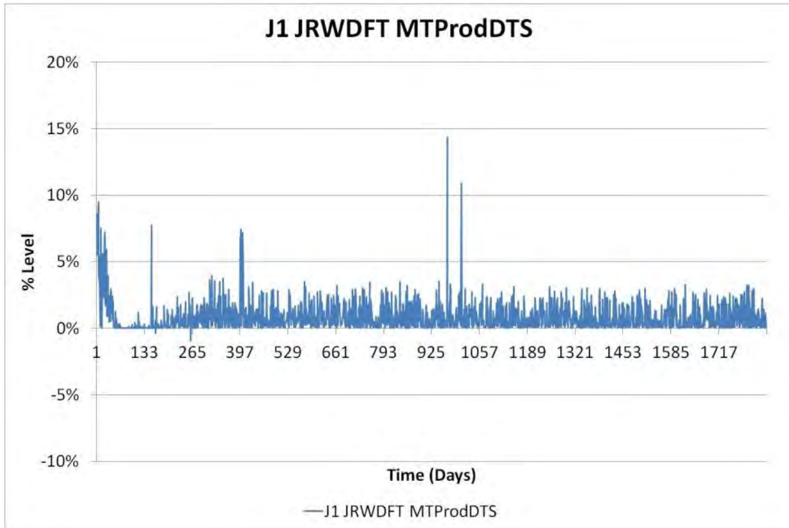
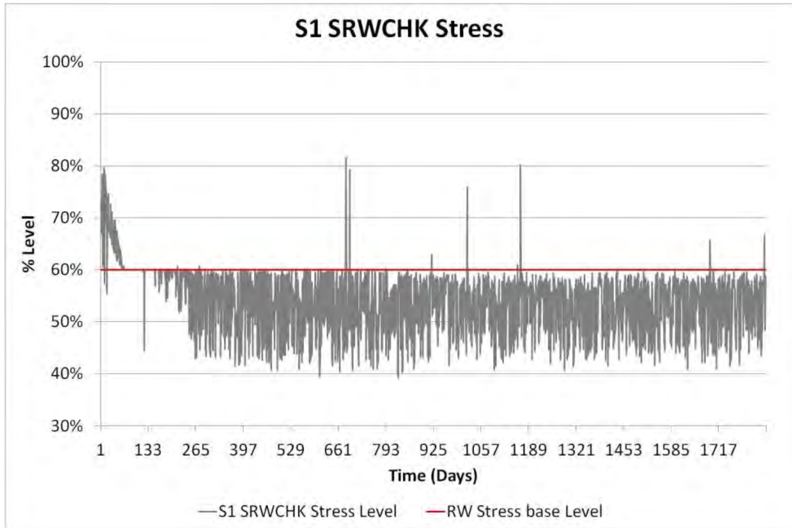


Figure 5.14: J1 JRWDFT MTProdDTS



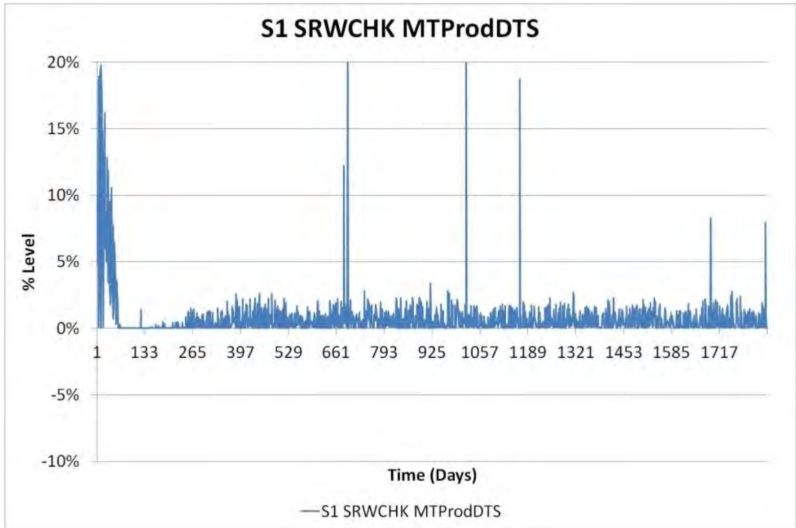


Figure 5.16: S1 SRWCHK Stress Level

Figure 5.15: S1 SRWCHK MTProdDTS

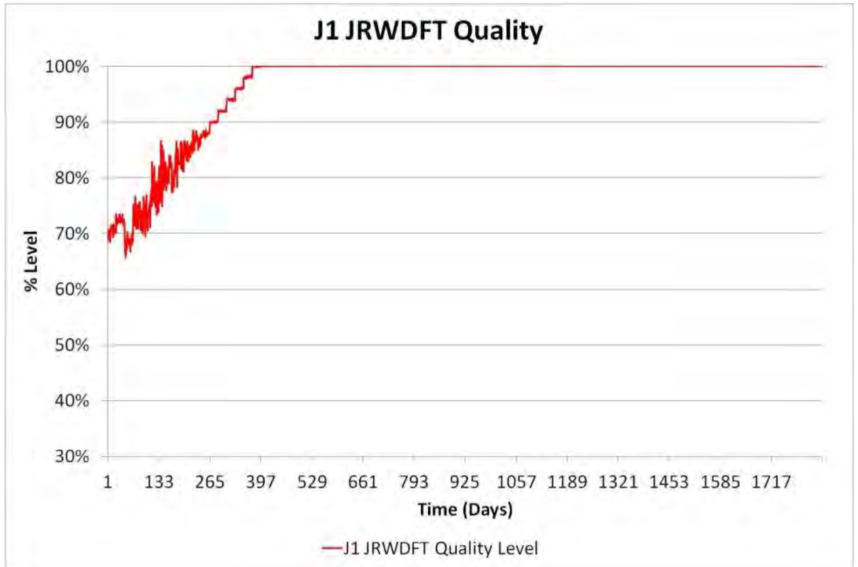


Figure 5.18: J1 JRWDFT Quality Level

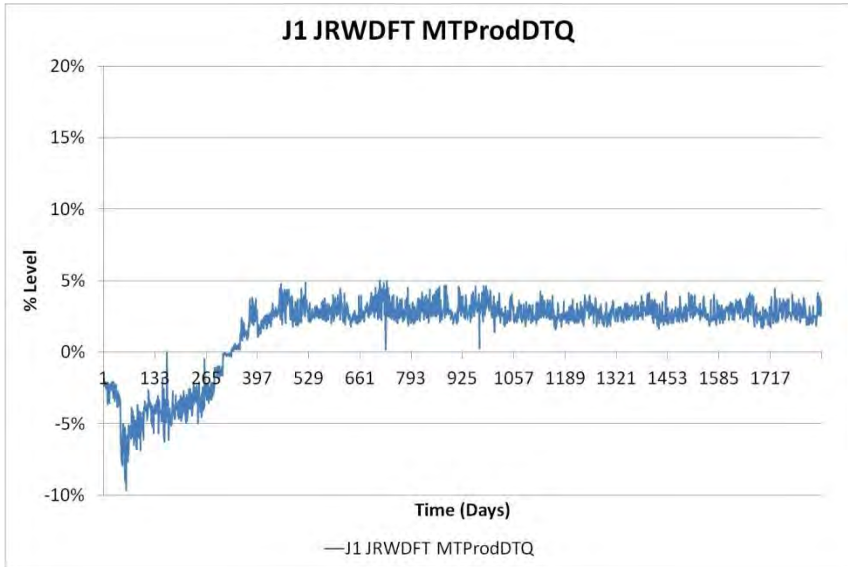


Figure 5.17: J1 JRWDFT MTProdDTQ

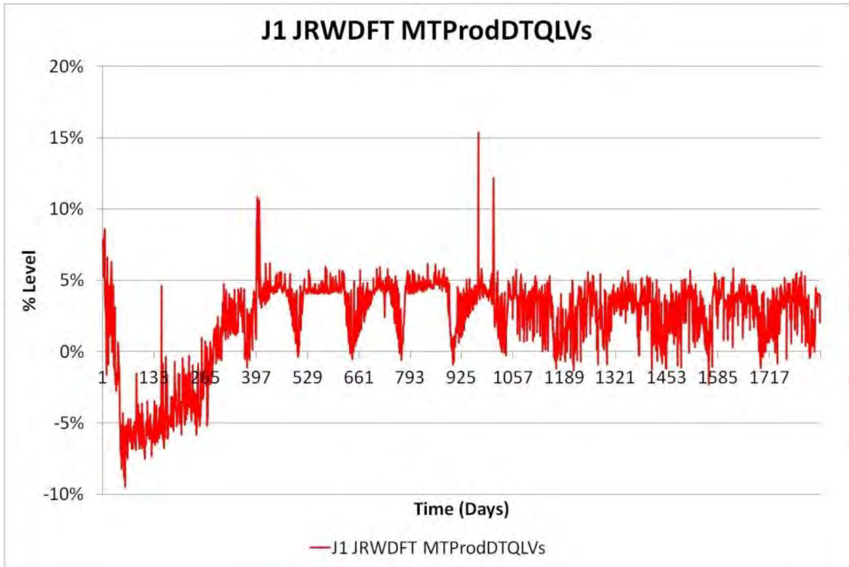


Figure 5.19: J1 JRWDFT MTProdDTQLVs

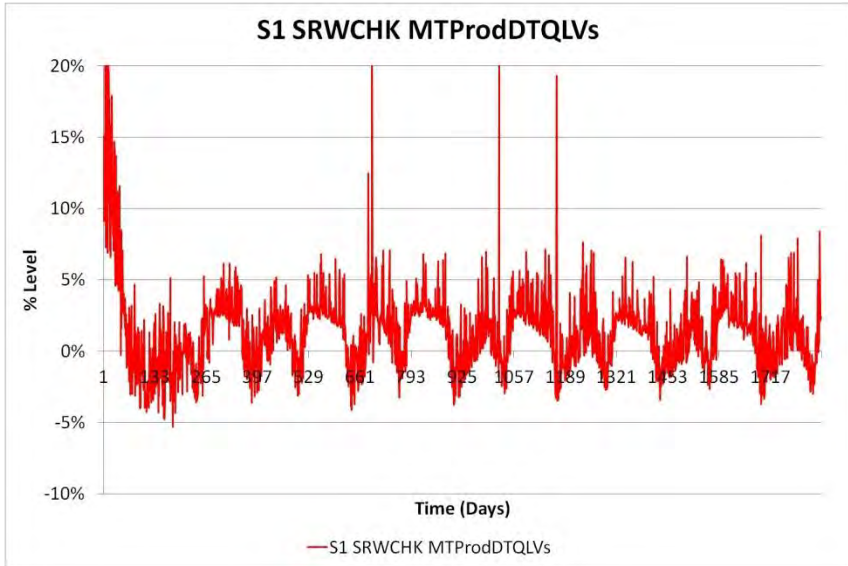


Figure 5.20: S1 SRWCHK MTProdDTQLVs

5.2.3 Multiplier to Productivity Due to Qualitative Variables

We now analyse the multiplier to productivity of each qualitative variables by increasing their levels by 20% from 0% to 100% all else constant. Our objective is to determine how much of an impact changing the levels of each qualitative variable has on productivity. Table 5.2 to Table 5.8 illustrate the results from this simulation for J1 JRWDFT and S1 SRWCHK respectively.

Scenario	Sc. 1	Sc. 2	Sc. 3	Sc. 4	Sc. 5	Sc. 6
HEALTH LEVEL	**0%**	20%	40%	60%	80%	100%
J1 JRWDFT reports/week	**<0.1**	3.1	12.4	16.0	16.7	16.9
J1 JRWDFT MTProdDTQLVs	-100.0%	-81.7%	-26.2%	-1.8%	3.0%	4.3%
J1 JRWDFT MTProdDTH	**-100.0%**	-78.7%	-26.5%	-3.6%	<0.1%	2.2%
J1 JRWDFT % of Firm's Tasks	<0.1%	2.0%	7.4%	9.7%	10.1%	10.2%

Table 5.2: Effect of Health on J1 JRWDFT Productivity

Scenario	Sc. 1	Sc. 2	Sc. 3	Sc. 4	Sc. 5	Sc. 6
HEALTH LEVEL	**0%**	20%	40%	60%	80%	100%
S1 SRWCHK reports/week	**<0.1**	1.9	31.1	31.9	33.1	35.0
S1 SRWCHK MTProdDTQLVs	-100.0%	-94.7%	-7.7%	-3.1%	1.3%	8.5%
S1 SRWCHK MTProdDTH	**-100.0%**	-94.5%	-8.0%	-3.7%	<0.1%	7.8%
S1 SRWCHK % of Firm's Tasks	<0.1%	1.3%	18.6%	19.3%	20.0%	21.1%

Table 5.3: Effect of Health on S1 SRWCHK Productivity

Scenario	Sc. 1	Sc. 2	Sc. 3	Sc. 4	Sc. 5	Sc. 6
MORALE LEVEL	0%	20%	40%	60%	80%	100%
J1 JRWDFT reports/week	5.6	7.4	15.2	16.6	16.7	17.3
J1 JRWDFT MTProdDTQLVs	-68.0%	-57.4%	-7.5%	1.7%	2.7%	6.2%
J1 JRWDFT MTProdDTM	-68.0%	-57.1%	-7.5%	-0.3%	<0.1%	4.7%
J1 JRWDFT % of Firm's Tasks	3.4%	4.4%	9.1%	10.0%	10.1%	10.4%

Table 5.4: Effect of Morale on J1 JRWDFT Productivity

Scenario	Sc. 1	Sc. 2	Sc. 3	Sc. 4	Sc. 5	Sc. 6
MORALE LEVEL	0%	20%	40%	60%	80%	100%
S1 SRWCHK reports/week	24.6	25.8	33.0	33.3	33.4	36.0
S1 SRWCHK MTProdDTQLVs	-29.9%	-25.9%	0.5%	1.2%	1.6%	11.6%
S1 SRWCHK MTProdDTM	-29.9%	-26.3%	-0.8%	-0.2%	<0.1%	10.9%
S1 SRWCHK % of Firm's Tasks	14.8%	15.5%	19.8%	20.0%	20.1%	21.6%

Table 5.5: Effect of Morale on S1 SRWCHK Productivity

Scenario	Sc. 1	Sc. 2	Sc. 3	Sc. 4	Sc. 5	Sc. 6
STRESS LEVEL	0%	20%	40%	60%	80%	100%
J1 JRWDFT reports/week	17.3	17.3	17.0	16.7	**19.2**	4.2
J1 JRWDFT MTProdDTQLVs	7.1%	7.1%	4.4%	1.8%	20.0%	-76.0%
J1 JRWDFT MTProdDTS	6.4%	6.4%	3.5%	<0.1%	20.0%	**-76.0%**
J1 JRWDFT % of Firm's Tasks	10.4%	10.4%	10.2%	10.0%	11.5%	2.6%

Table 5.6: Effect of Stress on J1 JRWDFT Productivity

Scenario	Sc. 1	Sc. 2	Sc. 3	Sc. 4	Sc. 5	Sc. 6
STRESS LEVEL	0%	20%	40%	60%	80%	100%
S1 SRWCHK reports/week	35.0	35.0	33.7	33.4	**40.5**	14.9
S1 SRWCHK MTProdDTQLVs	7.8%	7.8%	2.8%	0.8%	30.0%	-60.0%
S1 SRWCHK MTProdDTS	7.4%	7.4%	2.2%	<0.1%	30.0%	**-60.0%**
S1 SRWCHK % of Firm's Tasks	21.0%	21.0%	20.2%	19.9%	24.3%	9.0%

Table 5.7: Effect of Stress on S1 SRWCHK Productivity

Scenario	Sc. 1	Sc. 2	Sc. 3	Sc. 4	Sc. 5	Sc. 6
QUALITY LEVEL	0%	50%	70%	90%	95%	100%
J1 JRWDFT reports/week	12.3	12.3	15.6	15.9	16.3	16.6
J1 JRWDFT MTProdDTQLVs	-25.9%	-25.9%	-3.8%	-2.3%	1.0%	3.5%
J1 JRWDFT MTProdDTQ	-26.2%	-26.2%	-4.3%	-2.9%	<0.1%	2.9%
J1 JRWDFT % of Firm's Tasks	7.4%	7.4%	9.5%	9.6%	9.9%	10.1%

Table 5.8: Effect of Quality on J1 JRWDFT Productivity

The vital results of the simulation are marked in red and discussed below.

Our analysis of results reveals mostly a positive relationship between increasing levels of qualitative variables and productivity (reports per week) with marginal productivity due to QLVs increasing with increasing levels of qualitative variables. At the lowest levels of health (0%) RWers' productivity is at zero, with the multiplier effect of health on productivity at -100%. Health levels have the greatest negative impact on productivity (-100% for J1 JRWDFT and -100% for S1 SRWCHK) when at its worst. Second to health are stress levels at their worst (100%) causing a reduction in productivity of -76% for J1 JRWDFT and -60% for S1 SRWCHK.

For J1 JRWDFT the highest level of productivity is when stress levels are at 80%, resulting in productivity of 19.2 reports per week. For S1 SRWCHK the highest level of productivity is also when stress levels are at 80%, resulting in productivity of 40.5 reports per week. As discussed in Chapter 3, the modelling of stress levels at levels above 80% means that the MTProdDTS has a 100% weighting in determining the MTProdDTQLVs. Initially at 80% the levels of stress have a relatively high positive multiplier effect on productivity which decreases when stress levels increase to 100% with the multiplier effect having a relatively large negative effect on productivity.

The change in qualitative levels also impacts the fraction of reports that individual RWers receive, with RWers receiving less reports at relatively adverse levels of qualitative variables. It must be noted that an increase in the MTProdDTQLVs does not necessarily bring about a direct proportional increase in the productivity of RWers. Productivity is limited by incoming flow of work to RWers. However, on an individual level given a constant firm task rate, if RWers have a relatively higher MTProdDTQLVs, all else constant, compared to their counterparts they receive more work their way.

The figures below (Figure 5.22 to Figure 5.27) graphically show the relationship between changes in the level of qualitative variables and productivity for J1 JRWDFT and S1 SRWCHK respectively. For health, morale and quality levels, the relationship with productivity is positive with increasing levels. The initial increase in stress levels from 0% to 80% shows a positive relationship with productivity, with productivity drastically dropping when stress levels are at 100%.

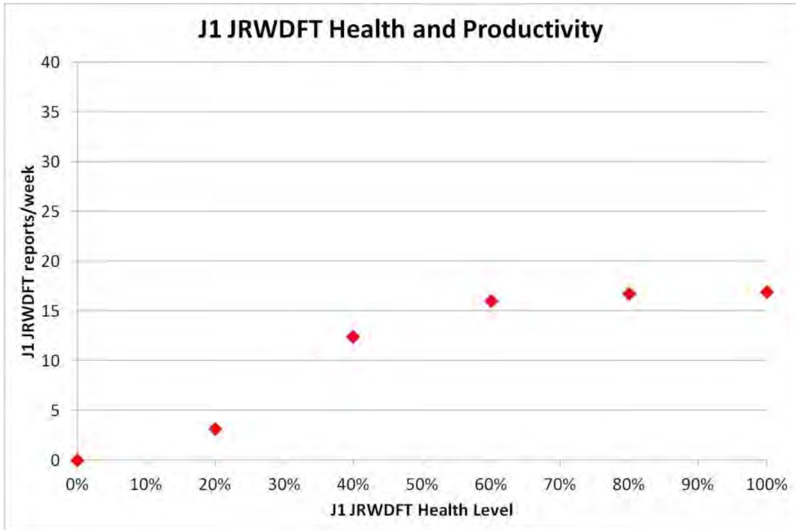


Figure 5.21: Effect of Health on J1 JRWDFT Productivity

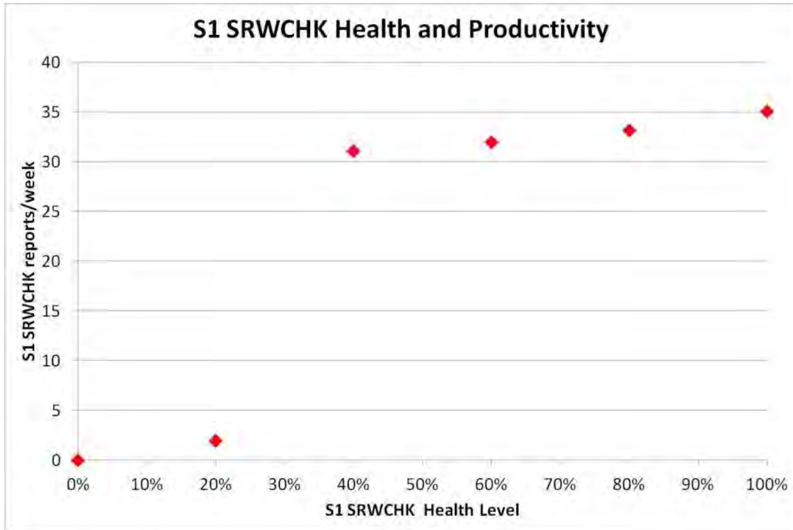


Figure 5.22: Effect of Health on S1 SRWCHK Productivity

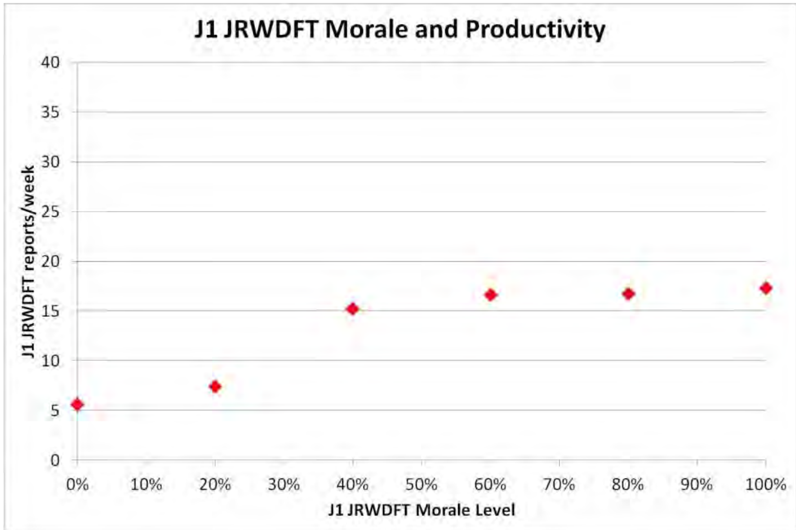


Figure 5.23: Effect of Morale on J1 JRWDFT Productivity

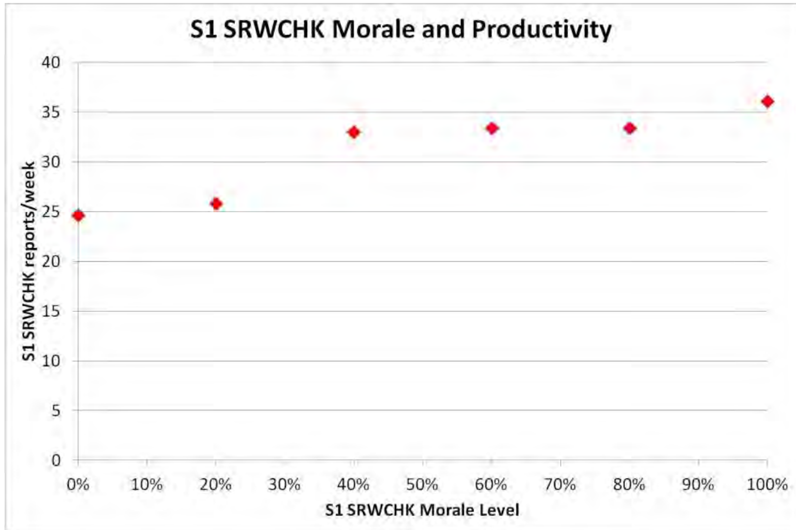


Figure 5.24: Effect of Morale on S1 SRWCHK Productivity

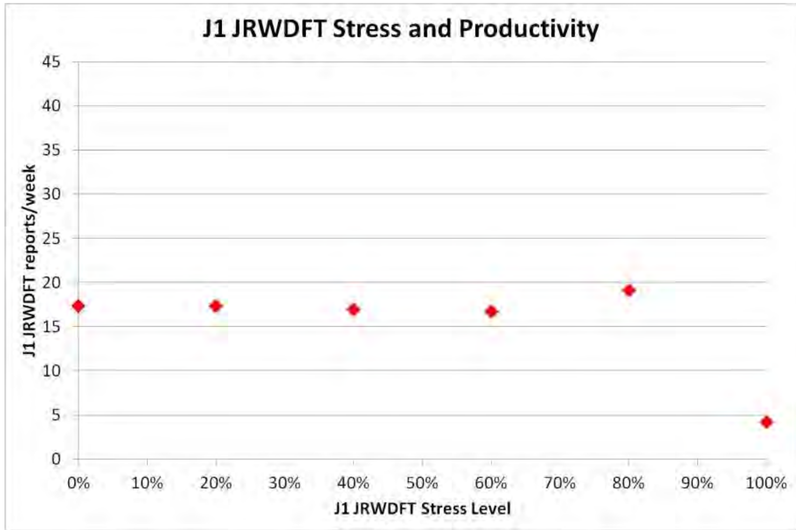


Figure 5.25: Effect of Stress on J1 JRWDFT Productivity

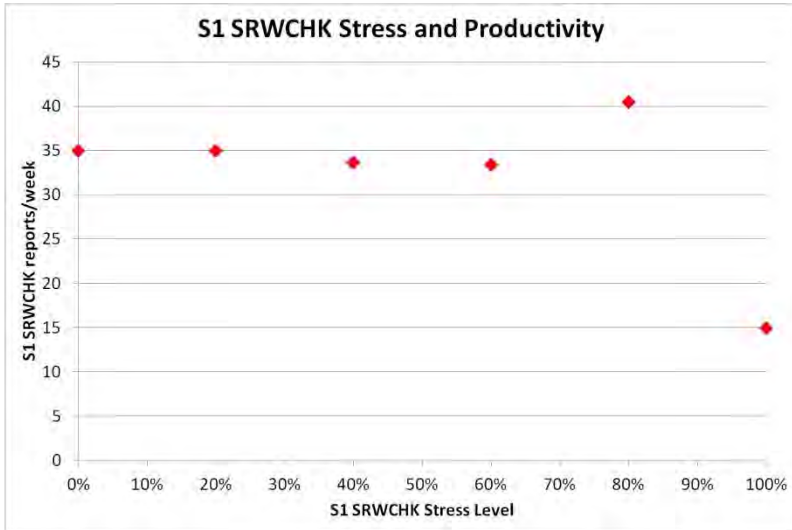


Figure 5.26: Effect of Stress on S1 SRWCHK Productivity

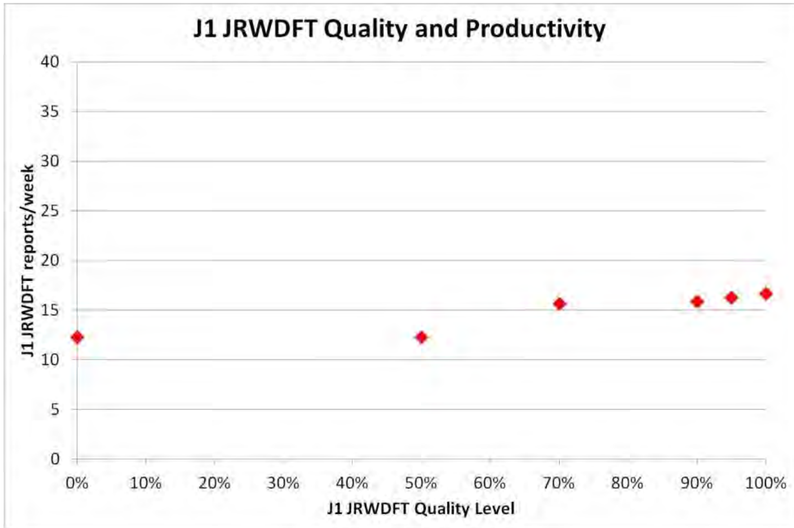


Figure 5.27: Effect of Quality on J1 JRWDFT Productivity

Table 5.9 and Table 5.10 give us an idea of which qualitative variables have the biggest positive impact on productivity when at their most optimal. As discussed, stress has the biggest impact on productivity when at its optimal for J1 JRWDFT, and similarly for S1 SRWCHK.

Scenario	Average	95% CI	
HEALTH LEVEL	100%		
J1 JRWDFT reports/week	16.91	16.90	16.92
J1 JRWDFT MTProdDTQLVs	4.31%	4.29%	4.32%
J1 JRWDFT MTProdDTH	2.18%	2.18%	2.18%
Scenario	**Average**	**95% CI**	
MORALE LEVEL	100%		
J1 JRWDFT reports/week	17.28	17.27	17.29
J1 JRWDFT MTProdDTQLVs	6.22%	6.20%	6.24%
J1 JRWDFT MTProdDTM	4.72%	4.71%	4.72%
J1 JRWDFT MTProdDTM	0.29%	0.29%	0.29%
Scenario	**Average**	**95% CI**	
STRESS LEVEL	80%		
J1 JRWDFT reports/week	19.20	19.19	19.21
J1 JRWDFT MTProdDTQLVs	20.00%	20.00%	20.00%
J1 JRWDFT MTProdDTS	20.00%	20.00%	20.00%
Scenario	**Average**	**95% CI**	
QUALITY LEVEL	100%		
J1 JRWDFT reports/week	16.66	16.65	16.67
J1 JRWDFT MTProdDTQLVs	3.49%	3.47%	3.51%
J1 JRWDFT MTProdDTQ	2.86%	2.85%	2.86%

Table 5.9: Effect of qualitative variables on productivity at optimal levels for J1 JRWDFT

Scenario	Average	95% CI	
HEALTH LEVEL	100%		
S1 SRWCHK reports/week	35.08	35.06	35.10
S1 SRWCHK MTProdDTQLVs	8.44%	8.43%	8.45%
S1 SRWCHK MTProdDTH	7.78%	7.77%	7.79%
Scenario	**Average**	**95% CI**	
MORALE LEVEL	100%		
S1 SRWCHK reports/week	36.01	35.99	36.04
S1 SRWCHK MTProdDTQLVs	11.55%	11.54%	11.57%
S1 SRWCHK MTProdDTM	10.87%	10.85%	10.88%
Scenario	**Average**	**95% CI**	
STRESS LEVEL	80%		
S1 SRWCHK reports/week	40.48	40.45	40.50
S1 SRWCHK MTProdDTQLVs	30.00%	30.00%	30.00%
S1 SRWCHK MTProdDTS	30.00%	30.00%	30.00%

Table 5.10: Effect of qualitative variables on productivity at optimal levels for S1 SRWCHK

The nature of feedback structures governed mainly by qualitative variables as well as quantitative variables, and their impact on productivity as well as other variables will become more apparent and discussed in more detail in the sections to follow.

5.3 Initial Hiring of Report Writers

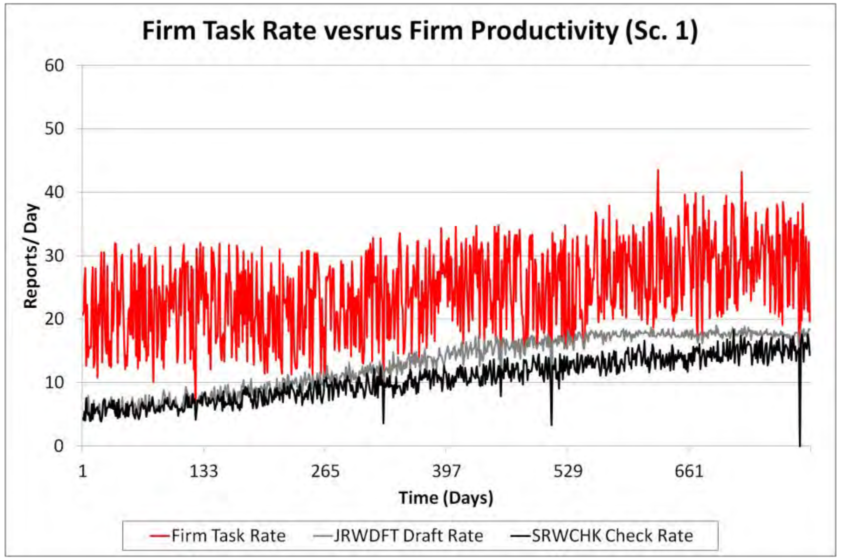
We now move on to a "what-if" analysis of the firm's initial hiring of RWers. As a recap, this analysis looks at the initial hiring of RWers, with the intention of analysis how capacity affects firm productivity and RWers' wellbeing. Our first scenario starts with 2 JRWers and 1 SRWer and with each subsequent scenario we increase the number of JRWers by 2, up until the last scenario of 14 JRWers. At the same time we increase the number of SRWers by 1, up until the last scenario with 7 SRWers.

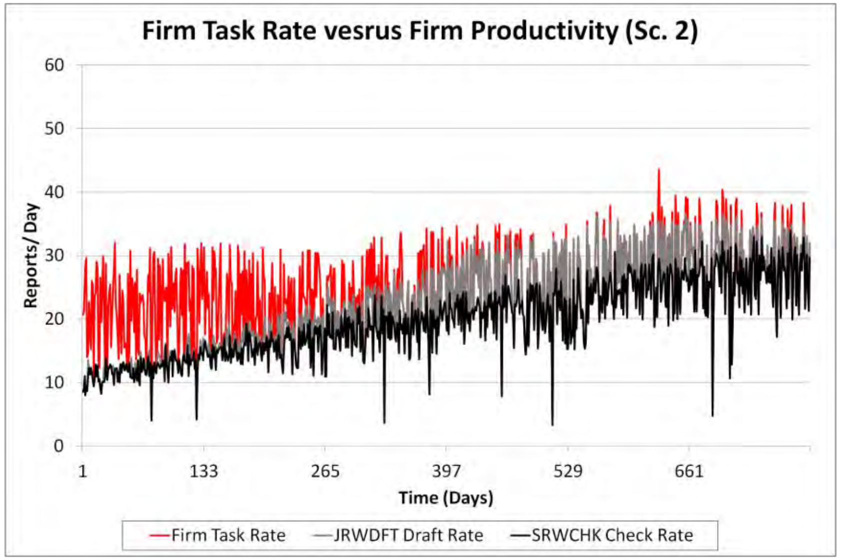
Scenario	Number of JRWDFTers	Number of SRWCHKers
Sc. 1	2	1
Sc. 2	4	2
Sc. 3	6	3
Sc. 4	8	4
Sc. 5	10	5
Sc. 6	12	6
Sc. 7	14	7

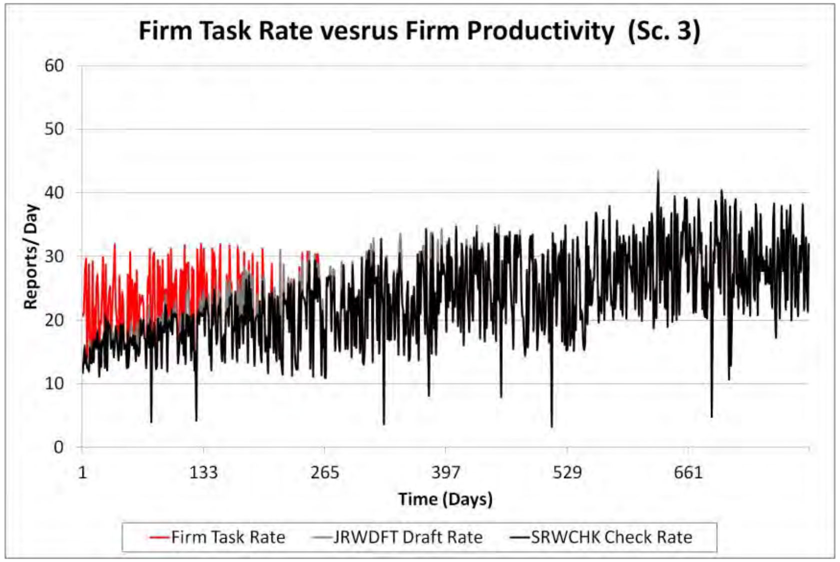
Table 5.11: Initial hiring of Report Writers scenarios

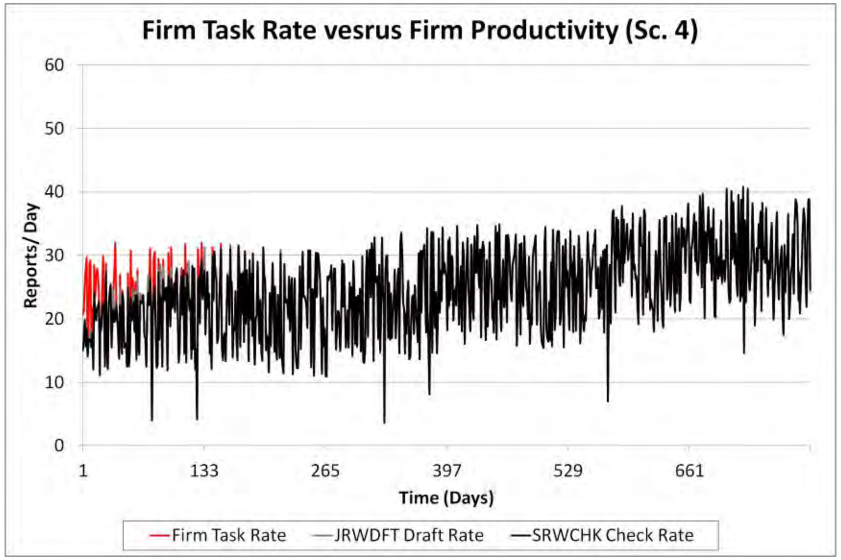
Our analysis looks at the first 3 years of the firm. From the cognitive mapping session it was clear that management were concerned about whether or not the firm would be able to manage the expected growing task rate but at the same time they want to ensure that after roughly 3 years the SRWers can be integrated into new actuarial projects away from report writing. At the same time management want to ensure that JRWers would have progressed from JRWDFTers to JRWSNDers by that stage to ensure the sustainability of the report writing section of the business.

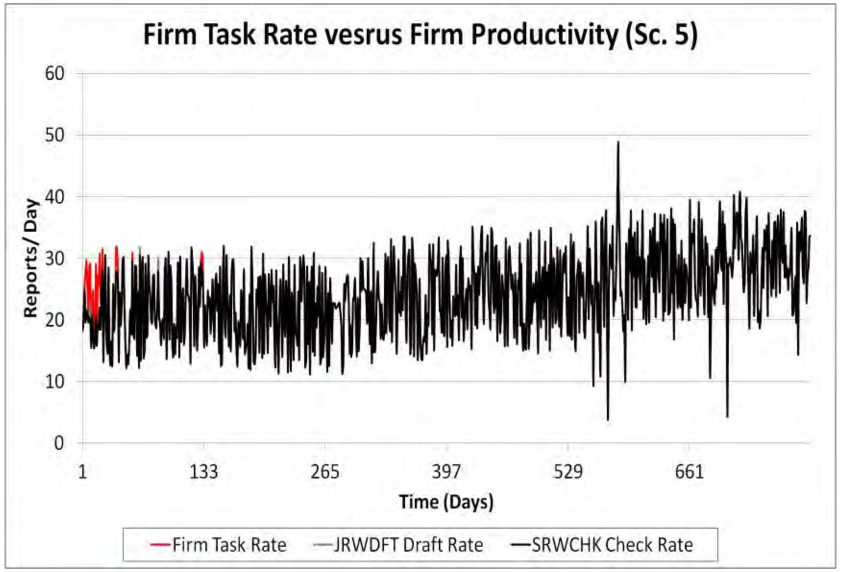
Figure 5.28 shows the firm's productivity under each scenario. The first 4 scenarios show how the firm struggles to match the task rate. The firm starts to match the firm task rate from when the firm capacity increases to 10 JRWDFTers and 5 SRWCHKers. The tables following the figures (Table 5.12 and Table 5.13) then illustrate the changes in the quantitative and qualitative variables with increasing capacity.

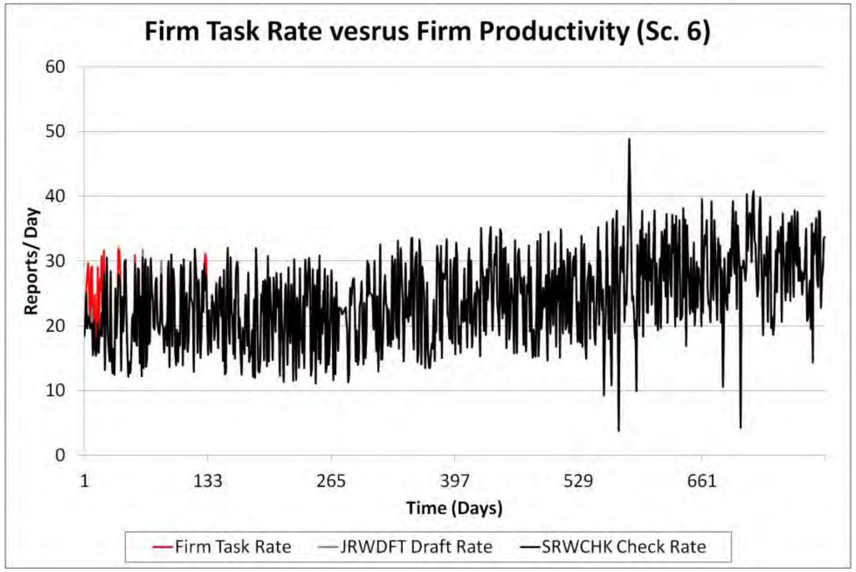

Firm Task Rate vesrus Firm Productivity (Sc. 1)
Reports/ Day
0
10
20
30
40
50
60
1
133
265
397
529
661
Time (Days)
Firm Task Rate
JRWDFT Draft Rate
SRWCHK Check Rate


Firm Task Rate vesrus Firm Productivity (Sc. 2)
Reports/ Day
0
10
20
30
40
50
60
1
133
265
397
529
661
Time (Days)
Firm Task Rate
JRWDFT Draft Rate
SRWCHK Check Rate


Firm Task Rate vesrus Firm Productivity (Sc. 3)
Reports/ Day
0
10
20
30
40
50
60
1
133
265
397
529
661
Time (Days)
Firm Task Rate
JRWDFT Draft Rate
SRWCHK Check Rate


Firm Task Rate vesrus Firm Productivity (Sc. 4)
Reports/ Day
0
10
20
30
40
50
60
1
133
265
397
529
661
Time (Days)
Firm Task Rate
JRWDFT Draft Rate
SRWCHK Check Rate





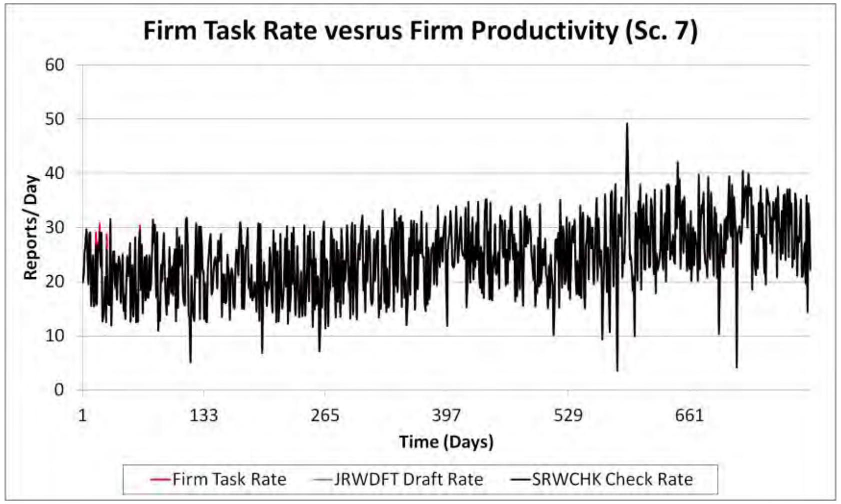


Figure 5.28: Firm Task Rate versus Firm Productivity with increasing Capacity

Sce.	Task Rate	Role	Number of RWs	Draft Rate/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed
Sc. 1	24.6	JRWDFT	2.0	13.1	99.3%	99.5%	99.2%
		SRWCHK	1.0	10.6	129.3%	99.5%	
Sc. 2	24.5	JRWDFT	4.0	21.7	84.8%	99.2%	66.0%
		SRWCHK	2.0	19.6	121.3%	99.2%	
Sc. 3	24.5	JRWDFT	6.0	23.7	64.4%	**99.0%**	**21.8%**
		SRWCHK	3.0	23.4	**99.1%**	**99.1%**	
Sc. 4	24.9	JRWDFT	8.0	24.6	56.4%	**61.5%**	**8.5%**
		SRWCHK	4.0	24.6	**79.2%**	**80.8%**	
Sc. 5	24.4	JRWDFT	10.0	24.2	**49.6%**	22.5%	4.7%
		SRWCHK	5.0	24.2	62.6%	28.9%	
Sc. 6	24.8	JRWDFT	11.0	24.7	47.7%	11.6%	3.3%
		SRWCHK	6.0	24.7	53.3%	11.6%	
Sc. 7	24.4	JRWDFT	14.0	24.4	**38.8%**	**<0.1%**	2.9%
		SRWCHK	7.0	24.4	**45.2%**	**<0.1%**	

Table 5.12: Initial hiring of RWs (Quantitative Variables)

Sce.	Role	% MTProdD TQLVs	Health Level	Health >base Level	MTProdDT H	Morale Level	Morale >base Level	MTProdD TM	Stress Level	Stress >base Level	MTProdDT S	Quality Level	MTProd DTQ
Sc. 1	JRWDFT	<0.1%	**74.3%**	**18.8%**	-1.0%	81.9%	67.0%	0.3%	61.1%	**99.5%**	0.4%	91.9%	0.3%
	SRWCHK	0.2%	**74.3%**	**24.7%**	-1.1%	81.1%	62.4%	0.5%	60.9%	**99.7%**	0.8%		
Sc. 2	JRWDFT	-0.1%	74.1%	12.0%	-1.0%	81.8%	70.5%	0.3%	61.0%	96.6%	0.4%	91.9%	0.3%
	SRWCHK	0.1%	74.4%	18.3%	-1.1%	81.1%	68.4%	0.5%	60.8%	99.1%	0.7%	-	-
Sc. 3	JRWDFT	-0.1%	74.1%	**10.4%**	-1.0%	81.8%	**70.7%**	0.3%	60.4%	**73.0%**	0.4%	91.9%	0.2%
	SRWCHK	<0.1%	74.3%	**14.1%**	-1.1%	81.1%	**71.0%**	0.5%	60.7%	**98.1%**	0.7%	-	-
Sc. 4	JRWDFT	0.4%	76.7%	**28.7%**	-0.7%	82.3%	**80.2%**	0.3%	57.7%	**38.5%**	0.7%	92.0%	<0.1%
	SRWCHK	0.3%	75.1%	**18.3%**	-0.9%	81.2%	**74.5%**	0.4%	59.3%	**73.6%**	0.8%	-	-
Sc. 5	JRWDFT	1.0%	79.3%	45.7%	-0.3%	82.8%	82.8%	0.3%	55.4%	20.1%	1.0%	91.9%	<0.1%
	SRWCHK	1.5%	78.8%	43.4%	0.1%	81.7%	83.8%	0.4%	55.5%	27.5%	1.0%	-	-
Sc. 6	JRWDFT	1.2%	79.8%	51.3%	-0.3%	82.8%	82.7%	0.3%	54.7%	14.1%	1.0%	91.9%	<0.1%
	SRWCHK	1.8%	80.0%	52.3%	0.4%	81.8%	87.5%	0.4%	54.2%	12.6%	1.0%	-	-
Sc. 7	JRWDFT	1.4%	**80.6%**	**57.6%**	-0.2%	83.0%	85.2%	0.3%	53.7%	**9.1%**	1.1%	91.9%	<0.1%
	SRWCHK	2.0%	**80.7%**	**59.8%**	0.5%	81.9%	88.5%	0.4%	53.4%	**5.6%**	1.0%	-	-

Table 5.13: Initial hiring of RWs (Qualitative Variables)

The vital results of the simulation are marked in red and discussed below, with the results marked in green forming the basis of our discussion below with regards to the significance of the impact that keys variables and feedback loops have on the behaviour of the system.

Looking at the Table 5.12 and Table 5.13 above for the initial 3 scenarios, the RWers are seemingly stretched in terms of working load with SRWCHKers working above 100% of their work capacity as they try and match the firm task rate with limited resources. From scenario 3 to scenario 4 there is a big drop in work capacity from 99.1% to 79.2% for SRWCHKers and deadlines missed from 21.8% to 8.5%. We also see how work capacity drops to less than 50% for scenario 5 for JRWDFTers when there are 5 JRWDFTers. At 14 JRWDFTers and 7 SRWCHKers the work capacity has drop below 50% for both and no overtime is worked.

We observe health, morale and quality levels increase as the number of RWers increases, with health showing the largest difference when comparing the extremes of scenarios (scenario 1 versus scenario 7) as the levels increase from 74% to 81% for both SRWers and JRWers. The differences in the levels between the extreme scenarios is better seen when taking a look at the percentage times that levels are above their base level. Here we see the increase of the percentage time that health levels are above 80% for JRWDFTers going from 18.8% to 57.6%. The difference is similarly as greater for SRWCHKers as we see the percentage time that health levels are above 80% go from 24.7% to 59.8%. The percentage time that stress levels exceed 60% when the number of RWers is 3 (scenario 1) is seemingly very high across all RWers (+99%), with the percentage decreasing to lower than 10% when the number of RWers increases to 21 (scenario 7).

Quality levels are seemingly not greatly affected by changes in the number of RWers with an average level of 91% across the 7 scenarios with stress and morale the only changing variables across the 7 scenarios that can affect quality. However, the decreasing impact of stress and morale over the first year of experience and the JRWDFTers' preference for quality before quantity, as noted in Chapter 3, means that there is no marked difference in quality over the 7 scenario.

Going back to Table 5.12 and Table 5.13, we note how key variables, rather than feedback loops, play a part in the changing levels of the qualitative variables as the number of RWers increase between each scenario (Equation 5.1 and Equation 5.2 below).The biggest increases in health levels (as well as health levels above base level) between scenario 3 and 4, and scenario 4 and 5 coincide with the biggest decreases in overtime (Equation 5.1 below illustrates key variables involved) and stress levels (Equation 5.2 below illustrates key variables involved). As the percentage SRWCHKers work capacity drops from 99% to below 79% between scenario 3 and scenario 4, we see a large drop in stress levels above base levels of 20% for SRWCHKers (Equation 5.2 below illustrates the key variables involved). The deceases in overtime, when work capacity is less than 100%, also allows for RWers more time to receive stress support and improve the stress management. In as similar way we see a big increase between scenario 3 and 4 in the percentage time that morale levels are above the base level as more support is offered and as health levels increase (Equation 5.3 below illustrates key variables involved).

Below we illustrate the key variables involved in the changes in levels above:

Increase in JRWers → increase in JRW draft rate → increase in firm productivity → decrease in deadlines missed → decrease in JRW overtime worked → positive multiplier effect of overtime on JRW health → increase in JRW health levels → positive multiplier effect of health on JRW draft rate.

Equation 5.1: Key variables behind change in Health

Key Note for Equation 5.1: It is evident from Equation 5.1 above that the biggest driver of increase in health levels is the decrease in overtime worked, which is mainly due to an increase in productivity brought about increasing the number of RWers.

Increase in JRWers → increase in JRW draft rate → increase in firm productivity → decrease in JRW work capacity → negative multiplier effect of work capacity on JRW stress → decrease in JRW stress levels → positive multiplier effect of stress on JRW draft rate.

Equation 5.2: Key variables behind change in Stress

Key Note for Equation 5.2: It is evident from Equation 5.2 above that the biggest driver of decrease in stress levels is the decrease in work capacity below 100%, which is mainly due to an increase in productivity brought about increasing the number of RWers.

Increase in JRWers → increase in JRW draft rate → decrease in JRW work capacity and overtime → positive multiplier effect of support on JRW morale → increase in JRW morale levels → positive multiplier effect of morale on JRW draft rate

AND

Increase in JRWers → increase in JRW draft rate → decrease in JRW overtime → decrease in negative multiplier effect of overtime on JRW health → increase in JRW health levels → increase in positive multiplier effect of health on JRW morale → increase in JRW morale levels → increase in positive multiplier effect of morale on JRW draft rate.

Equation 5.3: Key variables behind change in Morale

The tables below (Table 5.14 to Table 5.16) show the results of simulations of the model with 10 JRWDFTers and 5 SRWCHKers with the first table showing the quantitative statistics when considering qualitative variable in the model and the second table showing results from the model simulations when excluding qualitative variables from the model. 200 simulations were run for each model. We tested to see if there were any significant differences between the two sets of results.

Sce.	Task Rate	Role	Number of RWs	DR/ CR	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI		MTProdDTQLVs	95% CI	
Sce. 5A	24.47	JRWDFT	10.0	24.33	24.27	24.40	49.72%	49.56%	49.87%	23.1%	22.66%	23.46%	6.57%	6.32%	6.81%	0.95%	0.91%	0.98%
		SRWCHK	5.0	24.32	24.26	24.39	62.92%	62.73%	63.12%	28.1%	27.71%	28.57%				1.53%	1.50%	1.56%

Table 5.14: Scenario 5 - initial hiring of RWs with QLVS

Sce.	Task Rate	Role	Number of RWs	DR/ CR	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI		MTProdDTQLVs
Sce. 5A	24.45	JRWDFT	10.0	24.33	24.28	24.38	51.28%	51.13%	51.42%	13.6%	13.32%	13.89%	10.73%	10.43%	11.04%	-
		SRWCHK	5.0	24.30	24.25	24.35	62.78%	62.62%	62.95%	29.9%	29.50%	30.35%				-

Table 5.15: Scenario 5 - initial hiring of RWs without QLVS

Sce.	Role	Draft Rate/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed
Sce. 5A (p-values)	JRWDFT	0.49	<0.01	0.01	<0.01
	SRWCHK	0.46	0.42	<0.01	

Table 5.16: Scenario 5 - initial hiring of RWs p-values

With draft rate and check rate being mainly driven by firm task rate, there is no significant difference in draft rate/check rate between the model with qualitative variables and then model without qualitative variables. The incorporation of qualitative variables does, however, significantly lower the average work capacity, overtime worked and deadlines missed for JRWDFTers in comparison to when qualitative variables are excluded from the model. Similar results are obtained for SRWCHKers, with the exception of work capacity, where no significant difference is observed.

Going forward our base models will start with 10 JRWers and 5 SRWers, unless stated otherwise. We choose to use this as the base because at this capacity the process is somewhat in a stable state with RWers managing to match the required work rate with minimal, but evident, levels of overtime worked and percentage deadline missed. At this capacity we shall subject the models to different extreme events and various policy implementations and "what-if" analyses, exploring the stability of the process.

5.4 Allocation of Report Writers

In this analysis we take a look at the allocation of the different report writing roles. We categorize RWs into four main roles as follows, with their roles explained in the glossary:

1. JRWDFTers
2. SRWCHKers
3. JRWSNDers
4. SRWSNDers

The first scenario assumes that after 3 years the firm still adapts a quality checking phase where JRWDFTers have their work checked by SRWCHKers. The second scenario assumes that JRWDFTers would have progressed to become JRWSNDers after three years, and have earned the right to send their own work. By this time the quality of their work is 100%. The third scenario allows for a combination of JRWDFTers, SRWCHKers, JRWSNDers and SRWSNDers. This scenario assumes not all JRWDFTers are at that level where they can send their own reports and that they are unlikely to progress to that level in the period of analysis. As a result of this there is a need for SRWCHKers. However, some JRWDFTers have progressed to JRWSND status, therefore freeing up SRWCHKers, allowing them to draft and send their own work.

We wish to observe the impact of the different combinations on business process as a whole as set out above and in Section 4.3. The following figures give an indication of how well the firm copes with incoming work. In the instances where we have JRWSNDers and SRWSNDers, we group them together as one collective group known as RWSNDers.

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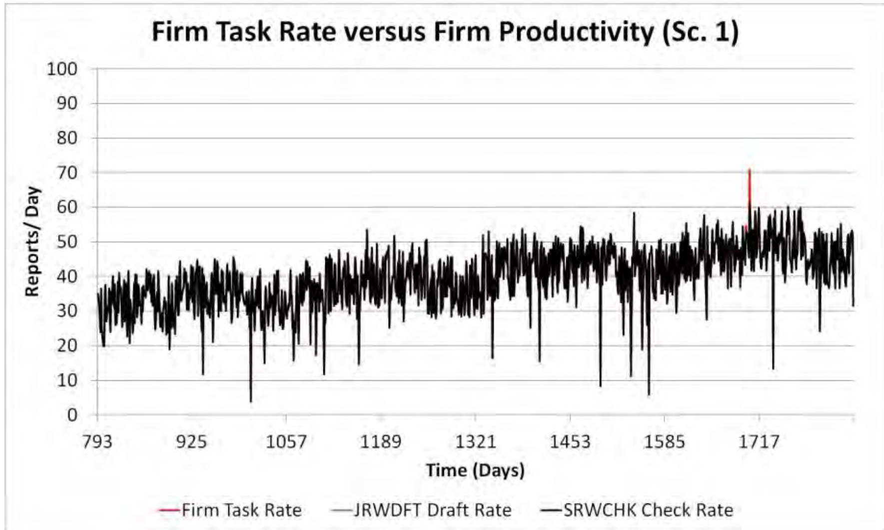

Figure 5.29: Scenario 1 - Firm Task Rate versus Firm Productivity allocation of RWers

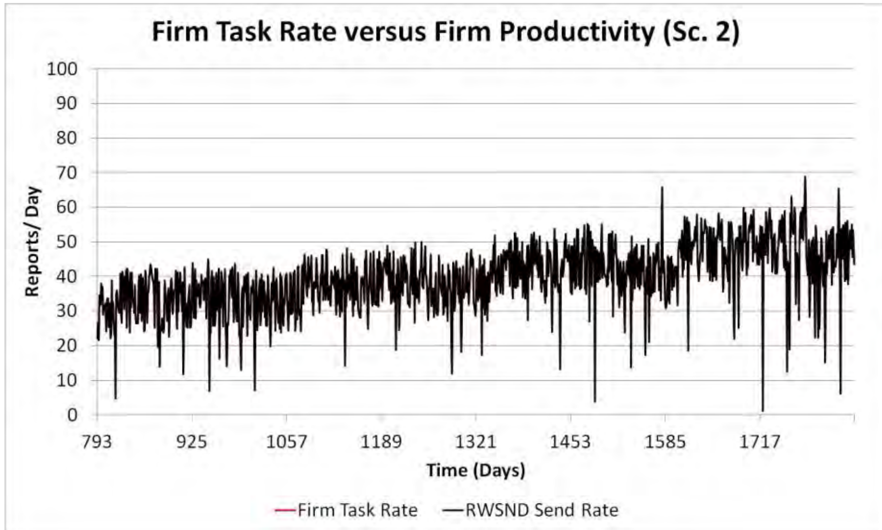

Figure 5.30: Scenario 2 - Firm Task Rate versus Firm Productivity allocation of RWers

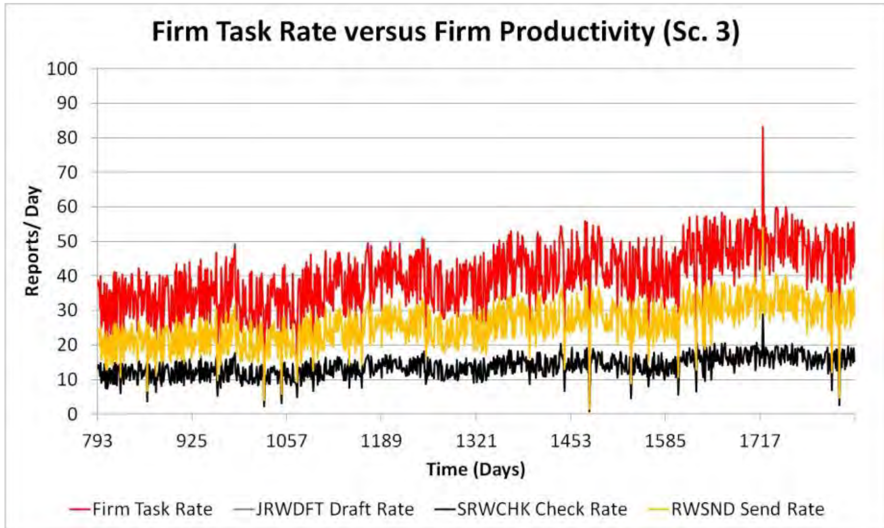

Figure 5.31: Scenario 3 - Firm Task Rate versus Firm Productivity allocation of RWers

Sce.	Task Rate	Role	Number of RWs	Draft Rate/ Check Rate	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 1	39.71	JRWDFT	10.0	39.70	39.62	39.79	**61.25%**	61.12%	61.38%	<0.01%	<0.01%	<0.01%	4.17%	3.97%	4.36%
		SRWCHK	5.0	39.70	39.62	39.79	54.32%	54.22%	54.42%	<0.01%	<0.01%	<0.01%			

Table 5.17: Scenario 1 - allocation of RWs with QLVs

Sce.	Role	Draft Rate/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed
Sce. 1 (p-values)	JRWDFT	0.35	0.35	-	0.45
	SRWCHK	0.35	0.30	-	

Table 5.18: Scenario 1 - allocation of RWs p-values

Sce.	Task Rate	Role	Number of RWs	Draft Rate/ Check Rate	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 2	39.58	JRWSND	10.0	18.74	18.70	18.78	**28.92%**	28.86%	28.99%	<0.01%	<0.01%	<0.01%	2.0%	1.85%	2.13%
		SRWSND	5.0	20.83	20.78	20.89	28.43%	28.37%	28.49%	<0.01%	<0.01%	<0.01%			

Table 5.19: Scenario 2 - allocation of RWs with QLVs

Sce.	Role	Draft Rate/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed
Sce. 2 (p-values)	JRWDFT	<0.01%	<0.01%	-	0.13
	SRWCHK	<0.01%	<0.01%	-	

Table 5.20: Scenario 2 - allocation of RWs p-values

Sce.	Task Rate	Role	Number of RWs	Draft Rate/ Check Rate	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 3	**39.69**	JRWDFT	5.0	**13.73**	13.70	13.76	42.39%	42.30%	42.48%	<0.01%	<0.01%	<0.01%	4.07%	3.88%	4.27%
		SRWCHK	3.0	**13.73**	13.70	13.76	31.57%	31.50%	31.63%	<0.01%	<0.01%	<0.01%			
		RWSND	7.0	**25.96**	25.90	26.02	30.30%	30.23%	30.36%	<0.01%	<0.01%	<0.01%			

Table 5.21: Scenario 3 - allocation of RWs with QLVs

Sce.	Role	Draft Rate/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed
Sce. 3 (p-values)	JRWDFT	<0.01%	<0.01%	-	0.40
	SRWCHK	<0.01%	<0.01%	-	
	RWSND	<0.01%	<0.01%	-	

Table 5.22: Scenario 3 - allocation of RWs p-values

Sce.	Role	MTProd DTQLVs	95% CI		Health Level	95% CI		Health Level >base	MTProd DTH	Morale Level	95% CI		Morale Level >base	MTProd DTM	Stress Level	95% CI		Stress Level >base	MTProd DTS	MTProd DTQ
Sce. 1	JRWDFT	3.12%	3.11%	3.13%	80.65%	80.58%	80.72%	57.5%	-0.13%	65.6%	65.50%	65.61%	5.30%	-0.40%	**53.10%**	53.09%	53.12%	<0.01%	0.84%	2.84%
	SRWCHK	1.29%	1.27%	1.30%	80.75%	80.68%	80.82%	80.8%	0.85%	64.7%	64.67%	64.79%	3.22%	-0.17%	**53.16%**	53.14%	53.19%	0.28%	0.61%	

Table 5.23: Scenario 1 - allocation of RWs QLVs

Sce.	Role	MTProd DTQLVs	95% CI		Health Level	95% CI		Health Level >base	MTProd DTH	Morale Level	95% CI		Morale Level >base	MTProd DTM	Stress Level	95% CI		Stress Level >base	MTProd DTS	MTProd DTQ
Sce. 2	JRWSND	3.07%	3.06%	3.08%	80.73%	80.66%	80.80%	58.6%	-0.13%	65.51%	65.45%	65.56%	4.83%	-0.39%	**52.69%**	52.67%	52.70%	<0.01%	0.82%	2.84%
	SRWSND	1.30%	1.29%	1.32%	80.77%	80.70%	80.84%	80.8%	0.85%	64.76%	64.70%	64.81%	3.03%	-0.16%	**52.65%**	52.63%	52.68%	0.19%	0.61%	

Table 5.24: Scenario 2 - allocation of RWs QLVs

Sce.	Role	MTProd DTQLVs	95% CI		Health Level	95% CI		Health Level >base	MTProd DTH	Morale Level	95% CI		Morale Level >base	MTProd DTM	Stress Level	95% CI		Stress Level >base	MTProd DTS	MTProd DTQ
Sce. 3	JRWDFT	3.05%	3.04%	3.06%	80.57%	80.50%	80.65%	57.1%	-0.14%	65.59%	65.53%	65.65%	4.55%	-0.39%	**52.82%**	52.80%	52.84%	0.09%	0.81%	2.84%
	SRWCHK	1.31%	1.29%	1.33%	80.66%	80.59%	80.73%	59.8%	0.83%	64.80%	64.74%	64.85%	3.03%	-0.16%	**52.95%**	52.92%	52.98%	<0.01%	0.64%	
	RWSND	2.58%	2.57%	2.59%	80.71%	80.64%	80.78%	58.3%	0.15%	65.36%	65.31%	65.42%	4.45%	-0.32%	**52.76%**	52.75%	52.78%	<0.01%	0.77%	

Table 5.25: Scenario 3 - allocation of RWs QLVs

The results show how in each of the scenarios RWers are able to cope with the incoming workload (Table 5.21) as the sum of the RWer draft/check rates (13.73 + 25.96 drafts per day) equate to the task rate (39.69 drafts per day). The most notable difference between the scenarios is the work capacity level, with scenario 1 showing the highest level of work capacity, with JRWDFTers having an average work capacity as high as 61.25%, and scenario 2 showing the lowest level of work capacity, with JRWDFTers having an average work capacity as low as 28.92%. With work capacity seemingly the worst affected key quantitative variable. But with work capacity figures all considerably below 100%, we do not see it impact stress significantly despite the inter-relationships involving the two variables (Equation 5.4 below). The fact that the RWers are able to manage the workflow in each scenario suggests that there are no major shocks to key quantitative and qualitative variables.

Change in work capacity → change in positive multiplier effect of leisure on JRW stress → change in JRW stress levels → change in multiplier effect of stress on JRW draft rate.

Equation 5.4: Feedback structures - Work capacity on Stress

Looking at the p-values comparing key variables when modelling with and without qualitative variables (Table 5.22), we see that with deadline missed being very low (less than 5%) across all scenarios there is no significant difference in deadlines missed. Work capacity and draft/check rates are significantly different when modelling with as opposed to without qualitative variables for the two scenarios, scenario 2 and 3.

5.5 Turnover of Report Writers

In this section, our model simulates a scenario where any 15 of the RWers (10 JRWSNDers and 5 SRWSNDers) can leave the firm at any point in time after an initial three years of experience (but within the 7 year period of analysis). After an initial three years' experience, we assumed that no RWers have left the firm and that the JRWDFTers have all progressed to JRWSNDers, therefore resulting in no checking phase. From the beginning of year 4 going forward, we modelled scenario 1 in such a way that any experienced RWer can leave the firm and is replaced by an equally experienced and skilled RWer, and in the alternative scenario we have modelled it such that the replacement RWer is subject to fluctuating changes in either health, morale or stress each month. The first figure below (Figure 5.32) shows the fluctuations in RWer numbers over time (similar for scenario 1 and 2). The figures that follow show the differences in the MTProdDTQLVs over time for JRWSNDers and SRWSNDers respectively for the two scenarios (Figure 5.33 and Figure 5.34). What follows are the tables showing the key performance indicators (Table 5.26 and Table 5.27) and changes in QLV factors for each respective scenario.

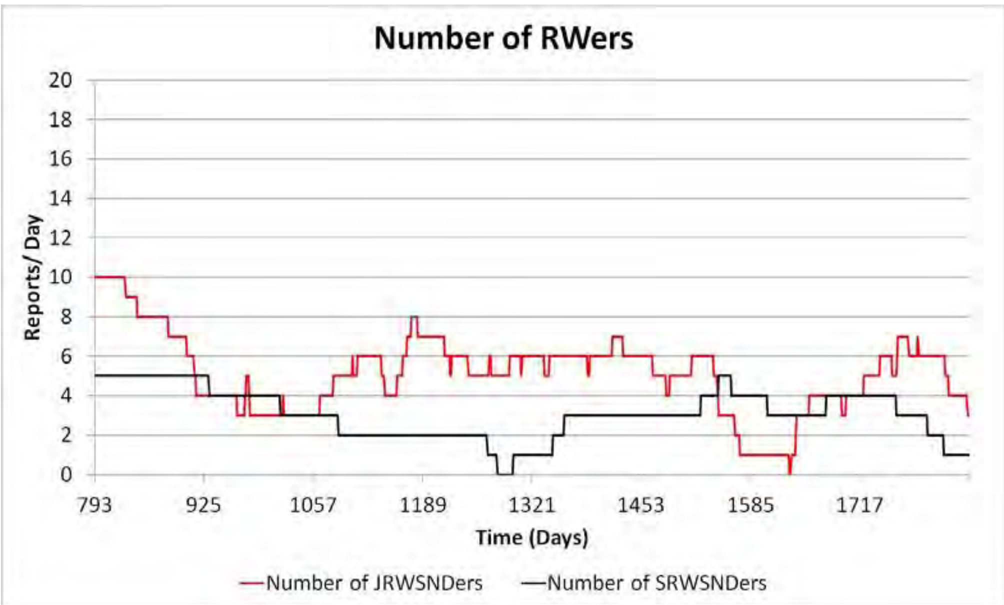

Figure 5.32: Number of RWers under turnover (scenario 1 and scenario 2)

The continuous turnover of RWers sees JRWSNDer numbers and SRWSNDers numbers going as low as zero as the firm struggles to quickly replace RWers.

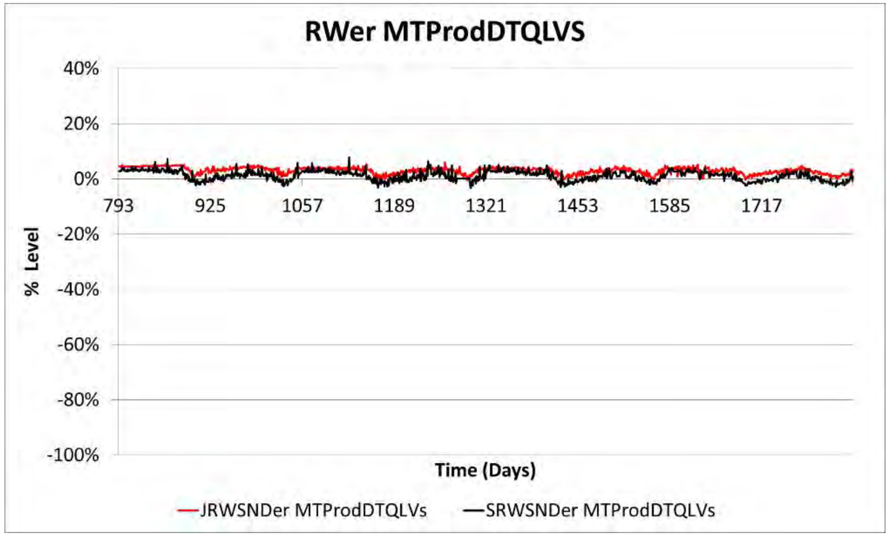

Figure 5.33: RWer MTProdDTQLVs under turnover (Scenario 1)

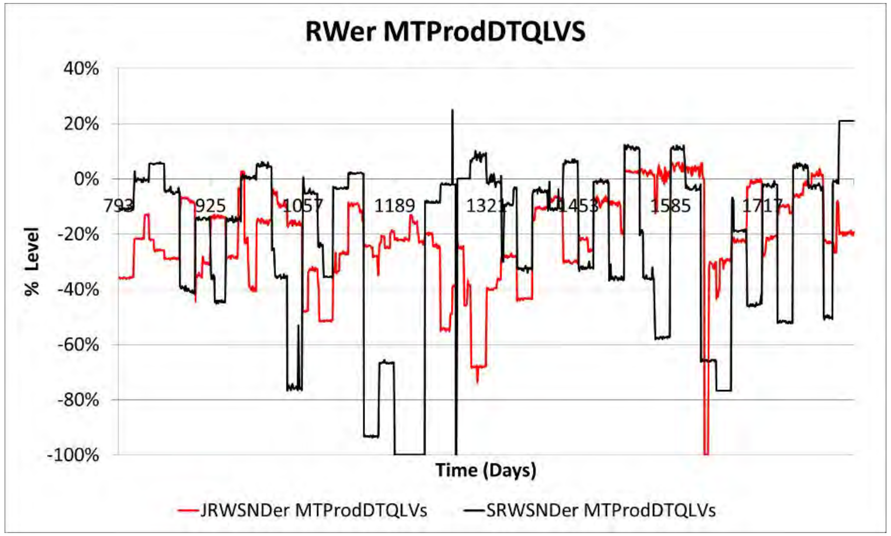

Figure 5.34: RWer MTProdDTQLVs under turnover (Scenario 2)

Sce.	Task Rate	Role	Number of RWs	95% CI		Draft/ Check Rate	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 1	39.76	JRWSND	5.12	5.10	5.13	**17.37**	17.30	17.44	53.39%	53.23%	53.56%	**7.52%**	7.32%	7.72%	**7.67%**	7.41%	7.93%
		SRWSND	3.09	3.07	3.10	**22.22**	22.14	22.30	**51.15%**	50.98%	51.33%	7.52%	7.32%	7.72%			

Table 5.26: Scenario 1 - RWer Turnover (with QLVs)

Sce.	Task Rate	Role	Number of RWs	95% CI		Draft/ Check Rate	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 2	40.10	JRWSND	**5.12**	5.10	5.13	**17.91**	17.82	17.99	45.70%	45.52%	45.89%	**75.03%**	74.61%	75.45%	**19.60%**	19.21%	19.99%
		SRWSND	**3.09**	3.07	3.10	**21.12**	21.03	21.21	**40.54%**	40.33%	40.76%	73.42%	72.99%	73.85%			

Table 5.27: Scenario 2 - RWer Turnover (with QLVs)

Sce.	Role	MTProd DTQLVs	95% CI		Health Level	95% CI		Health Level >base	MTProd DTH	Morale Level	95% CI		Morale Level >base	MTProd DTM	Stress Level	95% CI		Stress Level >base	MTProd DTS	MTProd DTQ
Sce. 1	JRWSND	3.02%	3.01%	3.03%	80.12%	80.04%	80.19%	53.8%	-0.18%	65.36%	65.29%	65.42%	4.73%	-0.40%	53.41%	53.38%	53.45%	0.19%	0.76%	2.84%
	SRWSND	1.12%	1.10%	1.14%	78.90%	78.78%	79.03%	78.9%	0.72%	63.65%	63.54%	63.75%	3.41%	-0.17%	52.40%	52.32%	52.48%	0.38%	0.57%	

Table 5.28: Scenario 1 - RWer Turnover QLVs

Sce.	Role	MTProd DTQLVs	95% CI		Health Level	95% CI		Health Level >base	MTProd DTH	Morale Level	95% CI		Morale Level >base	MTProd DTM	Stress Level	95% CI		Stress Level >base	MTProd DTS	MTProd DTQ
Sce. 2	JRWSND	-20.98%	-21.15%	-20.81%	64.93%	64.82%	65.04%	6.8%	-14.34%	54.62%	54.54%	54.71%	<0.01%	-8.34%	54.91%	54.84%	54.98%	23.11%	0.16%	1.54%
	SRWSND	-22.72%	-23.03%	-22.41%	57.34%	57.13%	57.56%	57.3%	-21.98%	54.64%	54.49%	54.79%	5.11%	-2.10%	54.77%	54.66%	54.87%	20.45%	1.36%	

Table 5.29: Scenario 2 - RWer Turnover QLVs

Sce.	Role	Draft/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed	MTProd DTQLVs	Health Level	Morale Level	Stress Level
Sce. 1&2	JRWSND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	SRWSND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 5.30: Scenario 1 and 2 turnover p-value

Looking at the MTProdDTQLVs illustrations (Figure 5.33 and Figure 5.34), we see that replacing RWers with equally skilled and experienced RWers results in a MTProdDTQLVs within a stable band, roughly -5% to +5%, which fluctuates above and below 0%. It stark contrast, we see that for the scenario where RWers are replaced by RWers who exhibit extreme fluctuations in either health, morale or stress, creates an average MTProdDTQLVs which varies greatly over time, reaching highs of +20% and lows of -100% (zero productivity). The volatile variation in scenario 2 of qualitative variables in contrast to the relatively stable variations in scenario 2 of qualitative variables, leads to a significantly differing productivity and wellbeing (Table 5.26 to Table 5.30).

Work capacity drops considerable for RWers between the two scenarios (Table 5.26 and Table 5.27), with SRWSNDer average work capacity dropping from 51.15% to 40.54%. Overtime worked is the worst affected key quantitative variable, as we see it drop from 7.52%, for JRWSNDers, to 75.03%. Deadlines missed also increase.

The negative effect of the multiplier effect, MTProdDTQLVs, in scenario 2, dropping from 3.02% to -20.98% and 1.12 to -22.72% for JRWSNDers and for SRWSNDers respectively, leads to RWers having to work more overtime to make up for the periods of low productivity (Table 5.28 and Table 5.29). The drop in MTProdDTQLVs is mainly attributed to significant decreases in health, with SRWSNDers showing significant drop in health levels from 78.90% to 57.34% and decreases in morale levels (see Equation 5.5 below). The volatility also attributes to more deadlines being missed (see Equation 5.6Equation 5.5 below).

Decrease in JRW health (or morale) levels → Decrease in multiplier effect of health (or morale) on JRW draft rate → Decrease in multiplier effect of qualitative variables on JRW draft rate.

Equation 5.5: Key variables – Health (or Morale) on Multiplier effect of qualitative variables on productivity

Volatility in number of RWers → volatility in draft rate → increase in deadlines missed

AND

Volatility in qualitative variables → volatility in multiplier effect of qualitative variables on productivity → volatility in draft rate → increase in deadlines missed

Equation 5.6: Key variables – Volatility in key variables on deadlines missed

Table 5.30 illustrates the significant differences in key variables between the 2 scenarios. Our analysis therefore shows how there are significant differences in productivity and wellbeing in the hiring of stable RWers as opposed to unstable RWers.

5.6 An analysis of Flexitime

We move on to the exploration of the concept of flexitime as we introduce it into our model. Our main focus in this analysis is to observe the impact flexitime has on keeping deadlines and its impact on morale for JRWSNDers. The results tables below (Table 5.33 to Table 5.35) compare the scenario of having no flexitime with that of having flexitime for JRWSNDers. The first figure below (Figure 5.35) illustrates the fluctuation in the number of RWers when flexitime is introduced. What follows is Figure 5.36 illustrating the difference in morale levels between scenario 1 – with flexitime and scenario 2 – without flexitime. The figures show how the number of JRWSNDers goes as low as 0 with the introduction of flexitime. Morale levels seem to be higher for JRWSNDers when flexitime is introduced.

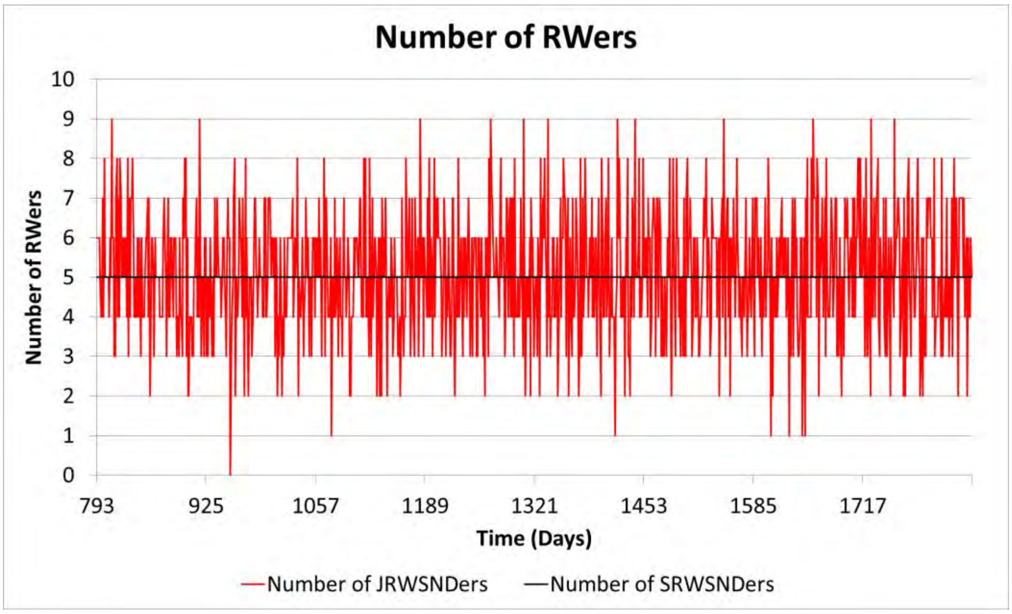

Figure 5.35: Number of RWers under flexitime (scenario 2)

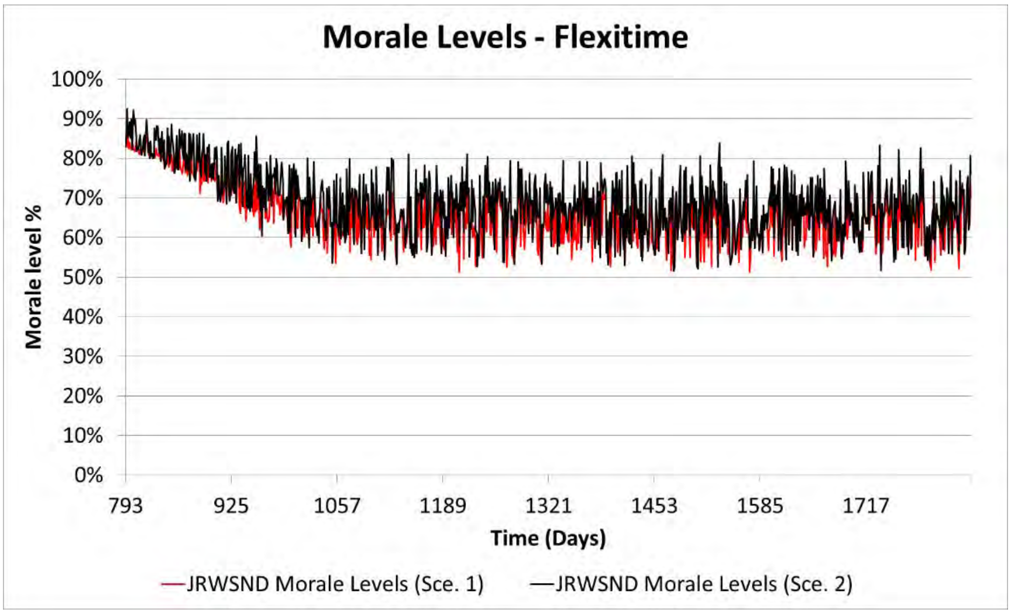

Figure 5.36: Scenario 1 vs Scenario 2 - Comparison of morale levels

Sce.	Task Rate	Role	Number of RWs	95% CI		Draft/ Check Rate	95% CI		% Days on Flexi	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 1	39.68	JRWSND	**10.00**	-	-	**18.82**	18.78	18.86	-	-	-	29.05%	28.99%	29.11%	<0.01%	-	-	3.22%	3.05%	3.39%
		SRWSND	5.00	-	-	**20.86**	20.81	20.91	-	-	-	**28.52%**	28.46%	28.59%	<0.01%	-	-			

Table 5.31: Scenario 1 - flexitime (with QLVs)

Sce.	Task Rate	Role	Number of RWs	95% CI		Draft/ Check Rate	95% CI		% Days on Flexi	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 2	39.68	JRWSND	**5.10**	5.08	5.11	**12.24**	12.21	12.28	48.11%	47.61%	48.60%	37.23%	37.03%	37.42%	<0.01%	-	-	3.60%	3.42%	3.78%
		SRWSND	5.00	-	-	**27.43**	27.36	27.51	-	-	-	**37.56%**	37.47%	37.65%	<0.01%	-	-			

Table 5.32: Scenario 2 - flexitime (with QLVs)

Sce.	Role	MTProd DTQLVs	95% CI		Health Level	95% CI		Health Level >base	MTProd DTH	Morale Level	95% CI		Morale Level >base	MTProd DTM	Stress Level	95% CI		Stress Level >base	MTProd DTS	MTProd DTQ
Sce. 1	JRWSND	3.10%	3.09%	3.12%	80.95%	80.87%	81.04%	58.33%	-0.13%	65.57%	65.49%	65.64%	5.59%	-0.38%	52.83%	52.79%	52.87%	0.85%	0.81%	2.77%
	SRWSND	1.24%	1.22%	1.27%	80.51%	80.43%	80.59%	80.51%	0.80%	64.70%	64.63%	64.78%	3.50%	-0.16%	52.69%	52.64%	52.74%	0.57%	0.63%	

Table 5.33: Scenario 1 - flexitime QLVs

Sce.	Role	MTProd DTQLVs	95% CI		Health Level	95% CI		Health Level >base	MTProd DTH	Morale Level	95% CI		Morale Level >base	MTProd DTM	Stress Level	95% CI		Stress Level >base	MTProd DTS	MTProd DTQ
Sce. 2	JRWSND	3.33%	3.32%	3.34%	80.95%	80.87%	81.03%	58.03%	-0.13%	69.12%	69.04%	69.20%	10.61%	-0.21%	52.97%	52.92%	53.01%	0.57%	0.81%	2.88%
	SRWSND	1.25%	1.23%	1.27%	80.51%	80.43%	80.59%	80.51%	0.80%	64.70%	64.63%	64.78%	3.50%	-0.17%	52.69%	52.64%	52.73%	0.57%	0.64%	

Table 5.34: Scenario 2 - flexitime QLVs

Sce.	Role	Draft/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed	MTProd DTQLVs	Health Level	Morale Level	Stress Level
Sce. 1&2	JRWSND	<0.01	<0.01	-	0.30	<0.01	-	<0.01	0.14
	SRWSND	<0.01	<0.01	-		0.01	-	-	0.46

Table 5.35: Scenario 1 and 2 flexitime p-values

Looking at the tables above (Table 5.31 and Table 5.32) we see how the introduction of flexitime significantly decreases the average number of JRWSNDers, from 10 to 5.10 on any given day. We observe how the percentage of deadlines missed is fractionally higher when flexitime is introduced, but not significantly different (p-value equal to 0.30). Productivity for both JRWSNDers and SRWSNDers has significantly changed with JRWSNDers doing less work on average (18.82 reports per day to 12.24 reports per day) as they spend more time away from reports. SRWSNDers are forced to take on a significantly larger amount of work, with average reports per day increasing by over 6 reports per day. For the remaining RWers in the office, the average work capacity increases as they attempt to take on the extra workload, with SRWSNDer work capacity increasing from 28.52% to 37.56%.

The introduction of flexitime, however, does not result in any significant change in overtime worked (Table 5.35). As a result of this, the impact on stress does not change significantly (p-values greater than 0.1). Flexitime does, however, significantly increase morale level (65.57% to 69.12%) and boosts the MTProdDTQLVs (3.10% to 3.33%) for JRWSNDers (Table 5.33 and Table 5.34), with Equation 5.5 showing the feedback loop involving morale and MTProdDTQLVs. However, as a result of JRWSNDers constantly leaving the office, the boost in MTProdDTQLVs is not there to be utilised within the report writing space. The burden of flexitime is definitely seen to fall on SRWSNDers as they must pick up a significant portion of the workload for JRWSNDers on flexitime (Table 5.31 and Table 5.32).

6 Discussion

6.1 Research Objectives

Our research set out to make use of business process modelling and model simulations to address objectives around various policy implementation and "what-if" scenarios at a start-up actuarial firm, highlighting the usefulness and adequacy of business process modelling and model simulations. We set out to evaluate the firm's business process under the perception that the behaviour of the firm's business process was governed by complex dynamic feedback structures. The business process model was built from information and data provided by various stakeholders involved in the process in the style of Morecroft *et al.* (2008). The data and information formed the basis from which we modelled the relationships between and amongst quantitative and qualitative variables. We set ourselves a target of tackling five main objectives using the business process modelling approach. The objectives gave us insights into (1) the impact that qualitative variables have on RWer productivity, (2) "what-if" scenarios around the initial hiring of RWers, (3) understanding the implications of allocating RWers into different roles as a means to improve productivity, (4) "what-if" analysis around the continuous turnover of experienced RWers and the impact it would have on firm productivity over time, (5) the impact that the introduction of a flexible working arrangement would have on RWers' productivity and well-being.

Through a combination of methods involving data collection, discussions, meetings and a cognitive mapping session we were able to build a model that exhibited a few feedback loops, with the model simulations of the objectives revealing that feedback loops did not play a significant role in governing the behaviour of the business process.

6.2 Research Discussion

Although the results suggested that feedback loops did not significantly impact the behaviour of the system, a number of interesting features emerged from our modelling process. We highlight the usefulness of our model simulations in our case study in Table 6.1 below. The first two columns in Table 6.1 look at the insights management expected based on how they had mentally modelled the process and the insights one would expect based on the model schematic in chapter 3 (Figure 3.8) respectively. The third column in Table 6.1 then summarizes the conclusions drawn from the model simulations. The table highlights the importance of using a suitable approach in modelling complex processes that may bring about unexpected results.

Objective		Management's Expected Insights	Insights from Model Schematic Diagram	Simulation Insights
1	Analysis of qualitative variables	Investing in improving RWer wellbeing (health, morale and stress) will result in higher productivity.	Changes in the level of qualitative variables through changes in other interlinked qualitative variables, latent variables and/or quantitative variables can bring about positive or negative changes to RWer productivity through inter-relationships and key variables.	Investing in improving RWer wellbeing will result in higher productivity. Mitigating adverse levels of qualitative variables ensures that productivity is not significantly negatively affected.
2	Initial hiring of RWers	Increasing number of RWers increases productivity.	Increasing number of RWers increases productivity. The extent to which productivity will increase is unknown given the dynamics of the inter-relationships and key variables.	No direct proportional relationship between productivity and increase in RWers, as highlighted with the increase in JRWDFTers from 6 to 8 JRWDFTers, which resulted in a much significant increase in productivity and changes in RWer wellbeing.
3	Allocation of RWers	Having RWers exclusively drafting and sending off own reports is the most effective combination.	It is uncertain which scenario will bring about the highest or lowest productivity given that it is unknown how the dynamics of the inter-relationships involving work capacity will affect productivity. An increase in work capacity may bring about a decrease in productivity as stress levels may increase beyond the threshold where stress has a negative impact on productivity or productivity may increase through the same inter-relationship. Hard to tell given the dynamic structures of the inter-relationships.	A scenario with just RWers drafting and sending reports results in higher work rate but lower levels of work capacity. A balance between meeting deadlines and utilising work capacity is desirable.

Objective	Management's Expected Insights	Insights from Model Schematic Diagram	Simulation Insights
4 Turnover of RWers	Turnover of experienced RWers will cause drop in firm productivity and cause deadlines to be missed.	It is hard to assess how much of an impact that turnover of RWers will have on the process as key variables and inter-relationships governing the level of qualitative variables are at play in determining the behaviour of the process. It is possible that the turnover may or may not have an impact on the business process. Impact is dependent on the significance of the impact the key variables and inter-relationships have on the process.	Turnover of experienced RWers will cause drop in firm productivity and cause deadlines to be missed. Replacement of RWers with volatile levels of health, morale and stress would negatively affect productivity (risk of hiring new and 'unknown quantities').
5 Analysis of flexitime	Flexitime will increase morale of RWers and boost productivity. Deadlines may be missed due to RWers out of office.	Intuitively flexitime should increases morale, with morale providing a positive effect on productivity. Potentially flexitime may have an adverse effect on productivity should too may RWer leave the office. This may leave RWers left in office to take on more work. Difficult to ascertain the extent to which flexitime has a positive or negative impact on productivity given the dynamics of the key variables and inter-relationships.	Flexitime increases morale but RWers are out of office too often for positive effect of morale on productivity to be realised within report writing. Flexitime has adverse effect on RWers left in office who must now take on more work.

Table 6.1: Insights of Management mental model and Insights from model schematic diagram.

What the table highlight is that mental modelling and model schematics give a general idea of how the business process potentially might behave when subjected to various "what-if" scenarios and policy implementations. However, because of the complex inter-relationships between the variables it is difficult to conclude how the process will behave under the various scenarios, and which variables will have the most effect on that behaviour. Furthermore, mental models or model schematics are not set up to explore the long term trends of the process over time. Business process modelling and simulation models allow for us to get a better understanding of the likely behaviour of the business process over time, and the key variables and inter-relationships behind the behaviour, as well as provide more meaningful information for decision makers, based on long run averages.

The methodology in modelling qualitative variables proved useful in assessing the impact of qualitative variables on productivity. The negative effect of qualitative variables on productivity is seen as quite significant, especially in scenarios where health levels or morale are relatively very low, or when stress levels are relatively very high. We also saw how qualitative variables have a significant impact on productivity and key variables such as work capacity and overtime, when the process is subjected to adverse conditions especially where RWer numbers are low or continuously fluctuating as seen in analysis of turnover and flexitime.

The analysis of the hiring process of RWers revealed that small increments in the number of RWers may result in a significantly large increase in productivity and RWer wellbeing. A trade-off is seen between minimising deadlines and overtime worked, and maximising work capacity as we go from relatively low numbers of RWers to relatively high numbers of RWers. The priority for the firm is essentially meeting deadlines, therefore having a relatively high number of RWers (10 JRWDFTers or more and 5 SRWCHKers or more) is ideal for minimising deadlines missed. But management must also look into measures that maximise work capacity as having relatively high numbers of RWers results in low levels of work capacity and hence underutilisation of RWers.

The results drawn from the analysis around the allocation of RWers revealed that each of the three scenarios around the allocation of RWers can be used if the priority of the firm is to minimise deadlines missed or overtime worked. Scenario 1 enforces a checking phases, which may be critical for quality control. Scenario 2 adopts a phase where some RWers can send their own reports and other RWers either draft or check reports.

The third scenario has no checking phase with all RWers sending their own reports. Scenario 1 is favourable in terms of ensuring a checking phase for quality control and also work capacity is much higher with this option. As a recap, we learnt from the cognitive mapping section that management are keen on fully utilising SRWers' potential outside of report writing and place them into various actuarial projects. This makes the third scenario favourable as it essentially allows for SRWers to move out of the report writing process with JRWSNDers ensuring that the firm is still able to manage incoming reports. The second option may be seen as a pilot phase for testing to see if the firm can migrate from option 1 (with a checking phase) to scenario 3 (with no checking phase).

The analysis of RWer turnover also highlighted the dangers of relying too much on mental models. A simple mental model of losing stable and experienced RWers may have lead management to conclude that the firm's productivity would not be significantly affected except for time when turnover is significantly high. Our analysis, however, suggested that the loss of experienced RWers in combination with a high turnover may indeed affect productivity but the consequences of hiring RWers that have volatile levels of health, morale or stress has a significant negative impact on productivity, percentage of deadlines met and overtime worked. Despite the rigor of the firm's recruitment process, the volatile levels of heath, morale or stress of the new recruits may only become apparent when they start working. This highlights the importance of retaining stable and experienced RWers that have proven to have relatively stable levels of health, morale and stress.

Another interesting insight was around the use of flexitime in order to boost productivity through a boost in morale. We saw that flexitime did indeed boost morale, but the high frequency in which RWers were in and out of the office meant that the positive impact of morale on productivity were hardly realised within the report writing process. A policy which allows for flexitime to be taken in such a way that the benefits of increased morale are realised by the firm may be more beneficial for the firm than randomly allocating flexitime.

Flexitime also goes a long way in adding appeal to the firm when it looks to recruit potential RWers in the future (Halpern, 2005). Prospective RWers may favour a firm that has a flexible working schedule over and above firms that do not offer flexitime. However, one of the major unintended consequences of flexitime is the strain that it puts on RWers who have to take on the extra workload left by RWers on flexitime. We observed a significant increase in the number of reports per day for the remaining RWers, and their work capacity increased significantly.

7 Conclusion

7.1 Conclusion

In conclusion, the modelling of the firm's business process revealed a process with numerous inter-relationships, including a few feedback loops. Therefore, instead of using mental models and model schematics to address the objectives, we made use of model simulations. This approach gave us a better understanding of some of the behaviour of the business process that was brought about mainly as a result of the significant key variables, inter-relationships between variables and allowing for potentially significant feedback loops. The simulation results also helped with providing insights to management around key variables and inter-relationships they should take into consideration when planning to implement policies that may potentially affect the business process.

Being a small start-up firm, we also wished to study the behavioural trends of the business process over time to get an idea of the potential short-term and long-term consequences of "what-if" analysis and policy implementations. Therefore, in these instances the model simulation approach was seen an appropriate approach that could be used to study the potentially complex business process of a start-up firm over time. Furthermore, this approach proved useful in conceptualising how people perceive the business process, pulling together their ideas and thoughts around it.

The results did bring to light the role that feedback loops play in determining the behaviour of the system. Through the model simulations, we saw that changes in the behaviour of the business process, in particular RWer productivity, were brought about mainly due to changes in certain key variables. For example, in studying the initial hiring of RWers (section 5.3), we saw that by increasing the number of RWers we were able to improve RWer productivity, as well as health, morale and stress. The key variables at play were the increase in RWers, which linked to increased productivity and decreased overtime and work capacity, which then affected the levels in qualitative variables.

We were able to establish that feedback loops, mainly governed by inter-relationships between qualitative variables, do not appear to have a significant impact on the behaviour of the process. This was mainly due to the fact that key variables, such as those mentioned above, had a greater impact on the behaviour of the process. In addition, the changes in the level of qualitative variables brought about by feedback loops were not significant in driving the change in behaviour of the system as their influence on productivity was relatively minimal through their respective multiplier effects on productivity (Figure 5.13 to Figure 5.20, page 101 to page 104).

Furthermore, our analysis of qualitative variables in section 5.2 highlighted that the changes in the level of qualitative variables were brought about largely due to changes in external variables rather than feedback loops. For example, the cyclic trend of health shown in Figure 5.5 and Figure 5.7 (page 96 and page 97 respectively) is mainly due to the seasonal component of exhaustion on health (as described on page 67). The role of external variables is evident when one sees variables such as exhaustion, job satisfaction and job stress heavily influencing the trend in the level of qualitative variables as shown in Figure 5.5 to Figure 5.12 on page 96 to page 99.

7.2 Research Limitations

The research approach allowed for us to make use of expert opinion and literature to make plausible assumptions around the modelling of certain variables and inter-relationships when data with respect to these was limited. This was useful given the time constraints experienced by all the participants of this research

We had initially set out to have a series of rounds of data gathering with each group, where in the first rounds we would gather information from RWers through questionnaires and from management through a cognitive mapping session. During the course of the research we planned to repeat this step of information gathering at least twice in order to verify if the information provided is consistent given the information provided in the initial phases. This would have given more credibility to the information. The information gathered based on questionnaires and discussions is also subject to question as it is unclear whether or not the RWers or management involved gave an honest response to the questions asked as noted by Dyer (1995).

However, even though the firm is relatively young and data and information with regards to the business process is relatively limited, we were able to use cognitive mapping, workshops, questionnaires and other data and information gathering techniques, to facilitate in the model building process. We managed to assess the consequences of various policy implementations and "what-if" scenarios, gaining insight into expected and unexpected results.

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Appendix

Appendix A. Glossary

Actuarial Reports

Reports quantifying (1) Motor vehicle accidents/Road Accident Fund Matters/3rd party claims (loss of income and loss of support), (2) Divorce and Estate claims (calculation of maintenance), (3) Medical Malpractice claims, which are drafted, checked and sent by Report Writers.

JRWer

Junior Report Writer. Not studying towards actuarial qualifications.

JRWDFTer

Junior Report Writer who strictly drafts actuarial reports.

RWer

Report Writer. Either a JRWDFT, SRWCHK, JRWSND or SRWSND.

SRWer

Senior Report Writer. Studying towards actuarial qualifications.

SRWCHKer

Senior Report Writer strictly checks actuarial reports.

JRWSNDer

A Junior Report Writer who strictly drafts and sends his/her own actuarial reports

Flexitime

Flexible working arrangement for JRWers.

MTProdDTQLVs

Multiplier to productivity due to qualitative variables.

MTProdDTH

Multiplier to productivity due to health.

MTProdDTM

Multiplier to productivity due to morale.

MTProdDTS

Multiplier to productivity due to stress.

MTProdDTQ

Multiplier to productivity due to quality.

MTHDTexh

Multiplier to health due to exhaustion.

MTHDTov

Multiplier to health due to overtime.

MTHDTsick

Multiplier to health due to sickness.

MTHDTstress

Multiplier to health due to stress.

MTMDTjobsat

Multiplier to morale due to job satisfaction.

MTMDTflex

Multiplier to morale due to flexible working arrangement.

MTMDThealth

Multiplier to morale due to health.

MTMDTsupport

Multiplier to morale due to support.

MTSDTwcap

Multiplier to stress due to work capacity.

MTSDTsupp

Multiplier to stress due to support.

MTSDTleisure

Multiplier to stress due to leisure.

MTSDTjobstress

Multiplier to stress due to job stress.

MTSDTurgent

Multiplier to stress due to urgent tasks.

MTQDTM

Multiplier to quality due to morale.

MTQDTstress

Multiplier to quality due to stress.

Management

Policy makers and implementers at the firm.

Stakeholders

All parties involved directly and indirectly in the firm's process

Flexi-time

Flexible working arrangement for JRWs or SRWs who are qualified actuaries

Health (burnout)

Physical or mental collapse caused by overwork or stress

Morale

The confidence, enthusiasm, and discipline of a person or group at a particular time

Stress

A state of mental or emotional strain or tension resulting from adverse or demanding circumstances

Quality

Percentage quality of drafts drafted by JRWs as graded by SRWs

Expectations

A belief that someone will or should achieve something

The variables and definitions were as follows (Oxford English Dictionary, 2008):

Salary A fixed regular payment, typically paid on a monthly basis but often expressed as an annual sum, made by an employer to an employee, especially a professional or white worker.

Example: *He received a salary of £24,000*

Leisure Time when one is not working or occupied; free time. Use of free time for enjoyment. Opportunity afforded by free time to do something.

Example: *writers with enough leisure to practise their art*

Development The process of developing or being developed.

Example: *she traces the development of the novel the paintings provide evidence of his artistic development*

Qualification A pass of an examination or an official completion of a course, especially one conferring status as a recognized practitioner of a profession or activity.

Example: *I left school at 15 with no qualifications*

Experience The knowledge or skill acquired by a period of practical experience of something, especially that gained in a particular profession.

Example: *You should have the necessary experience in health management*

Appendix B. Vensim Functions **(Garcia, 2006)**

ABS(A)

ABS calculate the absolute value of A, this means the positive value of a figure.

DELAY FIXED (X,T,N)

Delay in stair for the X value and the T period starting the simulation in N instead of X

IF THEN ELSE (Cond,X,Y)

The result is X if the condition is met, if the condition is not met the result is Y.

INTEGER OF X

Give as a result the whole part of the value X if it has decimals.

MAX (A,B)

Calculate the maximum of A and B.

MIN(A,B)

Calculate the minimum of A and B.

PULSE TRAIN (A,B,C,D)

Equal to the function PULSE but starting in the period A, with a duration of B periods, that repeats every C periods and letting it repeat itself after period D.

XIDZ (A,B,X)

The result is A/B, except when B = 0 then the result is X.

Appendix C. Key Equations

$J1\ JRWDFT\ QLV\ Factor_i =$

$J1\ JRWDFT\ MTProdDTh_i\ {*}J1\ JRWDFT\ hw_i{+}J1\ JRWDFT\ MTProdDTm_i{*}J1\ JRWDFT\ mw_i{+}J1\ JRWDFT\ MTProdDTs_i$

${*}J1\ JRWDFT\ sw_i{+}J1\ JRWDFT\ MTProdDTq_i{*}J1\ JRWDFT\ qw_i$

for i day = 1 to 1849

$S1\ SRWCHK\ QLV\ Factor_i =$

$S1\ SRWCHK\ MTProdDTh_i{*}S1\ SRWCHK\ hw_i{+}S1\ SRWCHK\ MTProdDTm_i{*}S1\ SRWCHK\ mw_i{+}S1\ SRWCHK\ MTProdDTs_i{*}S1\ SRWCHK\ sw_i$

for i day = 1 to 1849

$Task\ rate_{ti} = Task\ rate_{t0}{*}(1+\ growth\ factor_{ip}{*}(1{+}crisis\ fraction))$ *where*

$Task\ rate_{t0} \sim U(min_p,\ max_p)$

$Crisis\ fraction \sim U(0,0.05){*}h$, *where h take on the value 100% or -100% with equal probability*

for i=1 to7; p=quiet period, normal period, busy period

J1 JRWDFT draft rate$_i$ =

*min(J1 JRWDFT frac Tasks Incoming weight$_i$*Firm Task Rate$_i$,J1 JRWDFT Normal DR$_i$*(1+J1 JRWDFT QLV factor$_i$))*

for i day = 1 to 1849

J1 JRWDFT Normal DR$_i$ =

min((J1 JRWDFT initial DR$_i$+ J1 JRWDFT growth rate DR$_i$),J1 JRWDFT max)

for i day = 1 to 1849

J1 JRWDFT frac Tasks Incoming weight$_i$ =

if then else(Time=1,1/Number of JRWDFT$_i$, J1 JRWDFT frac Tasks Incoming$_i$ /JRWDFT frac Tasks Incoming$_i$)

for i day = 1 to 1849

S1 SRWCHK check rate$_i$ =

*min(S1 SRWCHK frac Tasks Incoming weight$_i$*Firm Draftt Rate$_i$,S1 SRWCHK Normal DR$_i$*(1+S1 SRWCHK QLV factor$_i$))*

for i day = 1 to 1849

J1 JRWDFT QLV Factor$_i$ $(_{\text{min=-100\%, max=100\%}})$ =

*J1 JRWDFT MTProdDTh$_{ik}$ *J1 JRWDFT hw$_{ik}$+J1 JRWDFT MTProdDTm$_{ik}$*J1 JRWDFT mw$_{ik}$+J1 JRWDFT MTProdDTs$_{ik}$*

**J1 JRWDFT sw$_i$+J1 JRWDFT MTProdDTq$_i$*J1 JRWDFT qw$_i$*

for i day = 1 to 1849, for k level = 0% to 100% and J1 JRWDFT hw + J1 JRWDFT mw + J1 JRWDFT sw + J1 JRWDFT qw = 1 *where J1 JRWDFT MTProdDTh*$_{ik}$ *, J1 JRWDFT MTProdDTm*$_{ik}$*, J1 JRWDFT MTProdDTs*$_{ik}$*, and J1 JRWDFT MTProdDTq*$_{i}$

J1 JRWDFT health level$_i$ **(**$_{min=0\%,\ max=100\%}$**)** *= J1 JRWDFT health base*(1 + J1 JRWDFT MThDTexh*$_{ik}$**J1 JRWDFT exhw*$_{ik}$ *+ J1 JRWDFT MThDTov*$_{ik}$**J1 JRWDFT ovw*$_{ik}$ *+ J1 JRWDFT MThDTsick*$_{ik}$** J1 JRWDFT sickw*$_{ik}$ *+J1 JRWDFT MThDTs* $_{ik}$** J1 JRWDFT sw*$_{ik}$*)*

for i day = 1 to 1849, for k level = -100% to 100% and J1 JRWDFT exhw + J1 JRWDFT ovw + J1 JRWDFT sickw + J1 JRWDFT sw = 1

J1 JRWDFT morale level$_i$ **(**$_{min=0\%,\ max=100\%}$**)** *= J1 JRWDFT morale base*(1 + J1 JRWDFT MTmDTjobsat*$_{ik}$**J1 JRWDFT jobsatw*$_{ik}$ *+ J1 JRWDFT MTmDTflex*$_{ik}$**J1 JRWDFT flexw*$_{ik}$ *+ J1 JRWDFT MTmDTh*$_{ik}$** J1 JRWDFThw*$_{ik}$ *+J1 JRWDFT MTmDTsupp* $_{ik}$** J1 JRWDFT suppw*$_{ik}$*)*

for i day = 1 to 1849, for k level = -100% to 100% and J1 JRWDFT jobsatw + J1 JRWDFT flexw + J1 JRWDFT hw + J1 JRWDFT suppw = 1

J1 JRWDFT stress level$_i$ **(**$_{min=0\%,\ max=100\%}$**)** *= J1 JRWDFT stress base*(1 + J1 JRWDFT MTsDTwcap*$_{ik}$**J1 JRWDFT wcapw*$_{ik}$ *+ J1 JRWDFT MTsDTsupp*$_{ik}$**J1 JRWDFT suppw*$_{ik}$ *+ J1 JRWDFT MTsDTleis*$_{ik}$** J1 JRWDFTleisw*$_{ik}$ *+J1 JRWDFT MTsDTjobstress* $_{ik}$** J1 JRWDFT jobstressw*$_{ik}$ *+J1 JRWDFT MTsDTurgent*$_{ik}$** J1 JRWDFT urgentw*$_{ik}$*)*

for i day = 1 to 1849, for k level = -100% to 100% and J1 JRWDFT wcapw + J1 JRWDFT suppw + J1 JRWDFT hw + J1 JRWDFT jobstressw + J1 JRWDFT urgentw = 1

J1 JRWDFT quality level$_i$ **(**$_{min=0\%,\ max=100\%}$**)** *= min((J1 JRWDFT initial QLT + J1 JRWDFT QLT growth constant+J1 JRWDFT MTqDsubj*$_{ik}$ **J1 JRWDFT SLD*$_{ik}$*)*(1+J1 JRWDFT MTqDTm*$_{ik}$ **J1 JRWDFT MTqDTmw*$_{ik}$ **J1 JRWDFT SLD*$_{ik}$ *+J1 JRWDFT MTqDTs*$_{ik}$ **J1 JRWDFT MTqDTsw*$_{ik}$ **J1 JRWDFT SLD*$_{ik}$*),1)*

for i day = 1 to 1849, for k level = -100% to 100% and J1 JRWDFT MTqDTmw$_{ik}$ *+ J1 JRWDFT MTqDTsw*$_{ik}$ *= 1*

S1 SRWCHK QLV Factor$_i$ $_{(min=-100\%, max=100\%)}$ =

*S1 SRWCHK MTProdDTh$_{ik}$ *S1 SRWCHK hw$_{ik}$+S1 SRWCHK MTProdDTm$_{ik}$*S1 SRWCHK mw$_{ik}$+S1 SRWCHK MTProdDTs$_{ik}$*

**S1 SRWCHK sw*

for i day = 1 to 1849, for k level = 0% to 100% and S1 SRWCHK hw + S1 SRWCHK mw + S1 SRWCHK sw = 1

where S1 SRWCHK MTProdDTh$_{ik}$, S1 SRWCHK MTProdDTm$_{ik}$, S1 SRWCHK MTProdDTs$_{ik}$,

***S1 SRWCHK health level$_i$ ($_{min=0\%, max=100\%}$)** = S1 SRWCHK health base*(1 + S1 SRWCHK MThDTexh$_{ik}$*S1 SRWCHK exhw$_{ik}$ + S1 SRWCHK MThDTov$_{ik}$*S1 SRWCHK ovw$_{ik}$ + S1 SRWCHK MThDTsick$_{ik}$* S1 SRWCHK sickw$_{ik}$ +S1 SRWCHK MThDTs $_{ik}$* S1 SRWCHK sw$_{ik}$)*

for i day = 1 to 1849, for k level = -100% to 100% and S1 SRWCHK exhw + S1 SRWCHK ovw + S1 SRWCHK sickw + S1 SRWCHK sw = 1

where **S1 SRWCHK health level$_i$** gives the health levels due to the combined effect of changing levels (k) of exhaustion, overtime, sick leave and stress, respectively. The variables are denoted as S1 SRW **M**ultiplier **T**o **h**ealth **D**ue **T**o overtime (ov), exhaustion (exh), sick leave (sick) and stress (s) respectively. S1 SRWCHK health base is the health level that brings about no change in productivity, in other words, S1 SRWCHK MTProdDTh is zero. Deviations from this base level are then brought about by changes in the variables stated above.

***S1 SRWCHK morale level$_i$ ($_{min=0\%, max=100\%}$)** = S1 SRWCHK morale base*(1 + S1 SRWCHK MTmDTSobsat$_{ik}$*S1 SRWCHK Sobsatw$_{ik}$ + S1 SRWCHK MTmDTflex$_{ik}$*S1 SRWCHK flexw$_{ik}$ + S1 SRWCHK MTmDTh$_{ik}$* S1 SRWCHKhw$_{ik}$ +S1 SRWCHK MTmDTsupp $_{ik}$* S1 SRWCHK suppw$_{ik}$)*

for i day = 1 to 1849, for k level = -100% to 100% and S1 SRWCHK Sobsatw + S1 SRWCHK flexw + S1 SRWCHK hw + S1 SRWCHK suppw = 1 where **S1 SRWCHK morale level$_i$** gives the morale levels due to the combined effect of changing levels (k) of exhaustion, overtime, sick leave and stress, respectively. The variables are denoted as S1 SRW **M**ultiplier **T**o **morale** **D**ue **T**o Sob satisfaction (Sobsat), flexitime (flex), health (h), support (supp) respectively. S1 SRWCHK morale base is the morale level that brings about no change in productivity, in other words, S1 SRWCHK MTProdDTm is zero. Deviations from this base level are then brought about by changes in the variables stated above.

S1 SRWCHK stress level$_i$ ($_{min=0\%,\ max=100\%}$) *= S1 SRWCHK stress base*(1 + S1 SRWCHK MTsDTwcap$_{ik}$*S1 SRWCHK wcapw$_{ik}$ + S1 SRWCHK MTsDTsupp$_{ik}$*S1 SRWCHK suppw$_{ik}$ + S1 SRWCHK MTsDTleis$_{ik}$* S1 SRWCHKleisw$_{ik}$ +S1 SRWCHK MTsDTSobstress $_{ik}$* S1 SRWCHK Sobstressw$_{ik}$ +S1 SRWCHK MTsDTurgent$_{ik}$* S1 SRWCHK urgentw$_{ik}$)*

for i day = 1 to 1849, for k level = -100% to 100% and S1 SRWCHK wcapw + S1 SRWCHK suppw + S1 SRWCHK hw + S1 SRWCHK Sobstressw + S1 SRWCHK urgentw = 1

where **S1 SRWCHK stress level$_i$** gives the stress levels due to the combined effect of changing levels (k) of work capacity, support, leisure time, Sob stress and urgent tasks, respectively. The variables are denoted as S1 SRW **M**ultiplier **T**o **stress** **D**ue **T**o Sob work capacity (wcap), support (supp), health (h), Sob stress (Sobstress) and urgent (urgent) respectively. S1 SRWCHK stress base is the stress level that brings about no change in productivity, in other words, S1 SRWCHK MTProdDTs is zero. Deviations from this base level are then brought about by changes in the variables stated above.

Qualitative Variable	Steady State	Affected by	Magnitude of effect as per
Health	80%	Exhaustion	Graphical function
		Overtime	Normal Distribution (-ve effect)
		Sick leave	Normal Distribution (+ve and –ve effect)
		Stress	Normal Distribution (-ve effect)
Morale	80%	jobsat	Normal Distribution (+ve and –ve effect)
		Flexi-time	Normal Distribution (+ve effect)
		Health	Graphical function
		support	Normal Distribution (+ve effect)
Stress	60%	wcap	Normal Distribution (+ve and –ve effect)
		supp	Normal Distribution (-ve effect)
		jobstress	Normal Distribution (+ve and –ve effect)
		Leisure time	Normal Distribution (-ve effect)
		jobstress	Normal Distribution (+ve effect)
Quality	-	subjectivity	Normal Distribution (+ve and –ve effect)
		Morale	Graphical function
		Stress	Graphical function

Table C.1: Summary of Modelling qualitative Variables

Appendix D. Other Results and Information Gathered

Year	January	February	March	April	May	June	July	August	September	October	November	December
2012	195	387	373	381	595	267	388	388	396	566	566	151
2013	211	511	524	431	702	479	361	485	536	605	603	305

Table D.1: Number of reports for the year 2012 and 2013

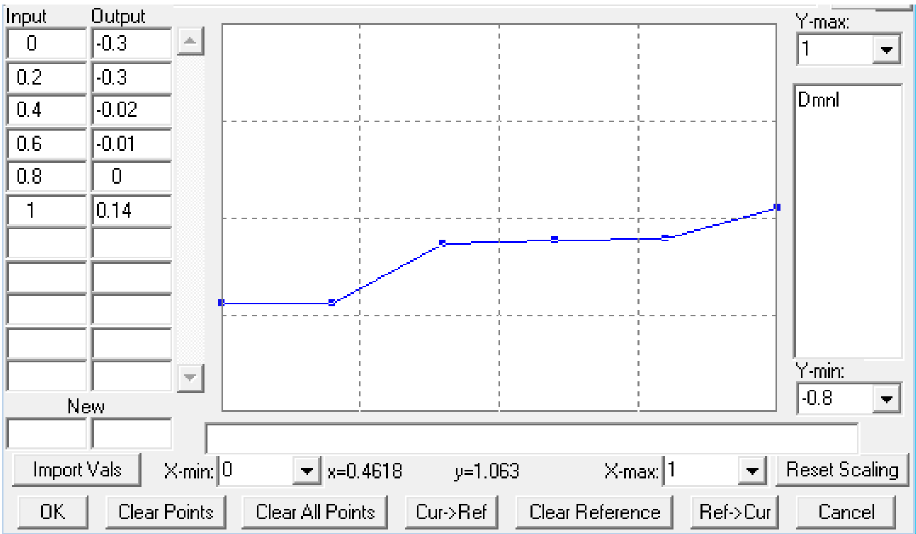


Figure D.2: Graphical Function SRWCHK MTProdDTm

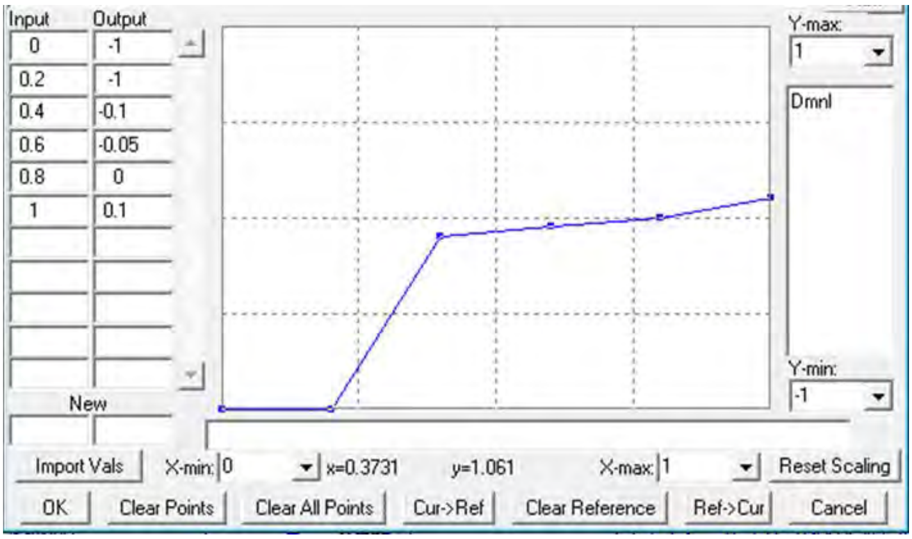


Figure D.1: Graphical Function SRWCHK MTProdDTh

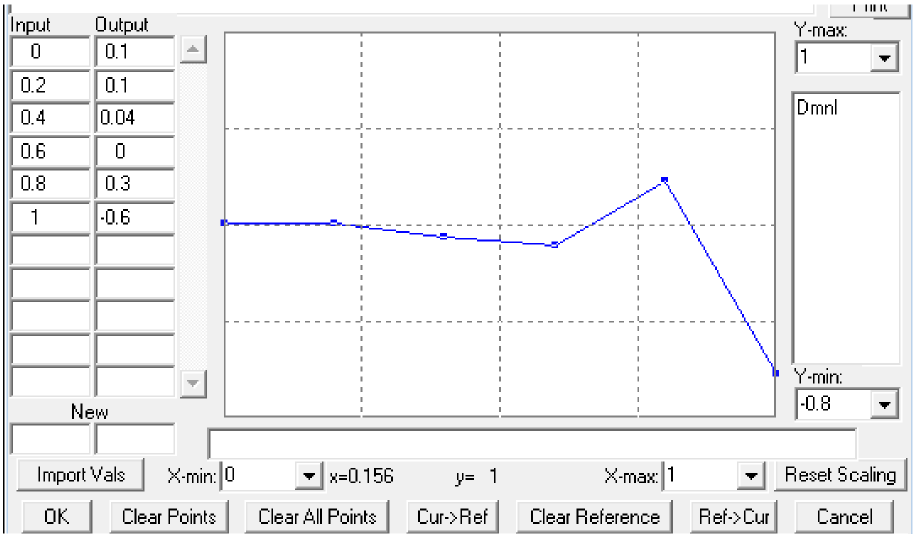


Figure D.3: Graphical Function SRWCHK MTProdDTs

JRWDFTer DATA collection Health

Health level	%ChangeProd		
<20%	-100%		
<40%	-36%		
<60%	-8%		
<80%	0%		
<100%	6%		
Exh	quiet	normal	busy
J1	27%	14%	-16%
J2	14%	0%	-16%
J3	14%	0%	-22%
J4	0%	0%	-29%
J5	0%	0%	-29%
Ave	11%	3%	-22%
SD	0.11	0.06	0.06
min	0%	0%	-29%
max	27%	14%	-16%
Overtime			
J1	0%		
J2	0%		
J3	-16%		
J4	-22%		
J5	-29%		
Ave	-13%		
SD	0.13		
min	-29%		
max	0%		

Sick	Plus	Minus	
J1	27%	-6%	
J2	14%	-6%	
J3	14%	-25%	
J4	0%	-25%	
J5	0%	-31%	
Ave	11%	-19%	
SD	0.11	0.12	
min	0%	-31%	
max	27%	-6%	
Stress	>80%		
J1	-14%		
J2	-14%		
J3	-14%		
J4	-29%		
J5	-29%		
Ave	-20%		
SD	0.08		
min	-29%		
max	-14%		
Exh	quiet	normal	busy
J1	27%	14%	-16%
J2	14%	0%	-16%
J3	14%	0%	-22%
J4	0%	0%	-29%
J5	0%	0%	-29%
Ave	11%	3%	-22%
SD	0.11	0.06	0.06
min	0%	0%	-29%
max	27%	14%	-16%

SRWCHKer DATA collection Health

Health level	**%ChangeProd**			
<20%	-100%			
<40%	-10%			
<60%	-5%			
<80%	0%			
<100%	10%			
Exh	quiet	normal	busy	
S1	14%	14%	-16%	
S2	14%	14%	-16%	
S3	14%	0%	-22%	
S4	14%	0%	-22%	
S5	0%	0%	-29%	
S6	0%	0%	-29%	
Ave	9%	5%	-22%	
SD	0.07	0.07	0.06	
min	0%	0%	-29%	
max	14%	14%	-16%	
Overtime				
S1	0%			
S2	0%			
S3	0%			
S4	-16%			
S5	-22%			
S6	-29%			
Ave	-11%			
SD	0.13			
min	-29%			
max	0%			

Sick	Plus	Minus	
S1	27%	-6%	
S2	14%	-6%	
S3	14%	-6%	
S4	0%	-25%	
S5	0%	-31%	
S6	0%	-31%	
Ave	9%	-18%	
SD	0.11	0.13	
min	0%	-31%	
max	27%	-6%	
Stress	>80%		
S1	-14%		
S2	-14%		
S3	-14%		
S4	-14%		
S5	-29%		
S6	-29%		
Ave	-19%		
SD	0.07		
min	-29%		
max	-14%		
Exh	quiet	normal	busy
S1	14%	14%	-16%
S2	14%	14%	-16%
S3	14%	0%	-22%
S4	14%	0%	-22%
S5	0%	0%	-29%
S6	0%	0%	-29%
Ave	9%	5%	-22%
SD	0.07	0.07	0.06
min	0%	0%	-29%
max	14%	14%	-16%

JRWDFTer DATA collection Morale

Morale level	%ChangeProd		
<20%	-68%		
<40%	-14%		
<60%	-2%		
<80%	0%		
<100%	10%		
jobsat	probation	promotion	saturation
J1	27%	27%	-13%
J2	25%	25%	-25%
J3	25%	25%	-25%
J4	24%	24%	-37%
J5	19%	19%	-38%
Ave	24%	24%	-27%
SD	0.03	0.03	0.10
min	19%	19%	-38%
max	27%	27%	-13%
flex			
J1	19%		
J2	14%		
J3	13%		
J4	6%		
J5	6%		
Ave	12%		
SD	0.05		
min	6%		
max	19%		

health	<20%	<40%	<60%	<80%	<100%
J1	-51%	-25%	0%	6%	11%
J2	-51%	-26%	-6%	1%	6%
J3	-63%	-31%	-6%	1%	6%
J4	-63%	-38%	-13%	0%	6%
J5	-69%	-38%	-13%	0%	0%
Ave	-59%	-32%	-8%	2%	6%
SD	0.08	0.06	0.05	0.03	0.04
min	-69%	-38%	-13%	0%	0%
max	-51%	-25%	0%	6%	11%
support					
J1	11%				
J2	6%				
J3	6%				
J4	0%				
J5	0%				
Ave	5%				
SD	0.05				
min	0%				
max	11%				

SRWCHKer DATA collection Morale

Morale level	%ChangeProd	
<20%	-30%	
<40%	-20%	
<60%	-1%	
<80%	0%	
<100%	14%	
jobsat	probation	saturation
S1	25%	-13%
S2	25%	-13%
S3	24%	-13%
S4	24%	-37%
S5	19%	-37%
S6	19%	-38%
Ave	23%	-25%
SD	0.03	0.13
min	19%	-38%
max	25%	-13%
flex		
S1	14%	
S2	14%	
S3	14%	
S4	13%	
S5	6%	
S6	6%	
Ave	11%	
SD	0.04	
min	6%	
max	14%	

health	<20%	<40%	<60%	<80%	<100%
S1	-51%	-25%	0%	6%	11%
S2	-51%	-26%	0%	1%	6%
S3	-51%	-26%	0%	1%	6%
S4	-63%	-31%	-6%	0%	6%
S5	-63%	-38%	-6%	0%	0%
S6	-63%	-38%	-13%	0%	0%
Ave	-57%	-31%	-4%	1%	5%
SD	0.06	0.06	0.05	0.02	0.04
min	-63%	-38%	-13%	0%	0%
max	-51%	-25%	0%	6%	11%
support					
S1	6%				
S2	6%				
S3	6%				
S4	0%				
S5	0%				
S6	0%				
Ave	3%				
SD	0.03				
min	0%				
max	6%				

JRWDFTer DATA collection Stress

Stress level	%ChangeProd		
<20%	12%		
<40%	8%		
<60%	0%		
<80%	20%		
<100%	-76%		
workcap	<50%	<150%	>200%
J1	0%	50%	67%
J2	0%	42%	65%
J3	0%	33%	65%
J4	-17%	33%	58%
J5	-17%	33%	58%
Ave	-7%	38%	63%
SD	0.09	0.07	0.04
min	-17%	33%	58%
max	0%	50%	67%
supp			
J1	-8%		
J2	-17%		
J3	-25%		
J4	-33%		
J5	-35%		
Ave	-24%		
SD	0.11		
min	-35%		
max	-8%		

leis	Plus	Minus			leisure 2012	
J1	0%	33%		J1	42.50	6.85
J2	-2%	25%		J2	37.50	6.93
J3	-8%	8%		J3	35.00	5.67
J4	-8%	8%		J4	35.00	6.00
J5	-8%	0%		J5	35.00	6.78
Ave	-5%	15%		Ave	37.00	
SD	0.04	0.14		SD	3.26	
min	-8%	0%		min	35.00	
max	0%	33%		max	42.50	
jobstress	probation	promotion	saturation			
J1	42%	33%	-7%	7%		
J2	42%	33%	-7%	7%		
J3	32%	23%	0%	0%		
J4	32%	23%	0%	0%		
J5	32%	23%	0%	0%		
Ave	36%	27%	-3%			
SD	0.05	0.05	0.04			
min	32%	23%	-7%			
max	42%	33%	0%			
urgent			**ave % urgent done**			
J1	50%		J1	20%		
J2	50%		J2	25%		
J3	33%		J3	40%		
J4	33%		J4	20%		
J5	32%		J5	20%		
Ave	40%		Ave	25%		
SD	0.09		SD	0.09		
min	32%		min	20%		
max	50%		max	40%		

SRWCHKer DATA collection Stress

Stress level	**%ChangeProd**				
<20%	10%				
<40%	4%				
<60%	0%				
<80%	30%				
<100%	-60%				
workcap	<50%	<150%	>200%		
S1	0%	50%	67%		
S2	0%	33%	67%		
S3	0%	33%	65%		
S4	0%	33%	65%		
S5	0%	33%	58%		
S6	-17%	33%	58%		
Ave	-0.03	0.36	0.63		
SD	7%	7%	4%		
min	-17%	33%	58%		
max	0.00	0.50	0.666667		
supp					
S1	-8%				
S2	-8%				
S3	-17%				
S4	-33%				
S5	-33%				
S6	-33%				
Ave	-22%				
SD	0.13				
min	-33%				
max	-8%				

leis	Plus	Minus			leisure 20:
S1	0%	25%		S1	35.00
S2	-2%	25%		S2	35.00
S3	-2%	15%		S3	35.00
S4	-9%	14%		S4	35.00
S5	-8%	0%		S5	35.00
S6	-8%	0%		S6	30.00
Ave	-5%	13%		Ave	34.17
SD	0.04	0.11		SD	2.04
min	-9%	0%		min	30.00
max	0%	25%		max	35.00
jobstress	probation	saturation			
S1	42%	-7%	7%		
S2	42%	-7%	7%		
S3	32%	0%	0%		
S4	32%	0%	0%		
S5	32%	0%	0%		
S6	32%	0%	0%		
Ave	35%	-2%			
SD	0.05	0.03			
min	32%	-7%			
max	42%	0%			
urgent					
S1	50%				
S2	50%				
S3	33%				
S4	33%				
S5	33%				
S6	33%				
Ave	39%				

JRWDFTer DATA collection Quality

Quality level	%ChangeProd				
<50%	-32%				
<70%	-8%				
<90%	-6%				
<95%	0%				
>99%	6%				
morale	<20%	<40%	<60%	<80%	<100%
J1	-40%	-30%	-5%	6%	11%
J2	-41%	-35%	-5%	1%	6%
J3	-50%	-35%	-10%	1%	6%
J4	-50%	-40%	-15%	0%	6%
J5	-90%	-70%	-15%	0%	0%
Ave	-54%	-42%	-10%	2%	6%
SD	0.21	0.16	0.05	0.03	0.04
min	-90%	-70%	-15%	0%	0%
max	-40%	-30%	-5%	6%	11%
stress	<20%	<40%	<60%	<80%	<100%
J1	0%	5%	9%	-1%	-1%
J2	-5%	1%	5%	-5%	-15%
J3	-5%	0%	5%	-5%	-40%
J4	-5%	0%	5%	-5%	-40%
J5	-10%	0%	0%	-15%	-45%
Ave	-5%	1%	5%	-6%	-28%
SD	0.04	0.02	0.03	0.05	0.19
min	-10%	0%	0%	-15%	-45%
max	0%	5%	9%	-1%	-1%

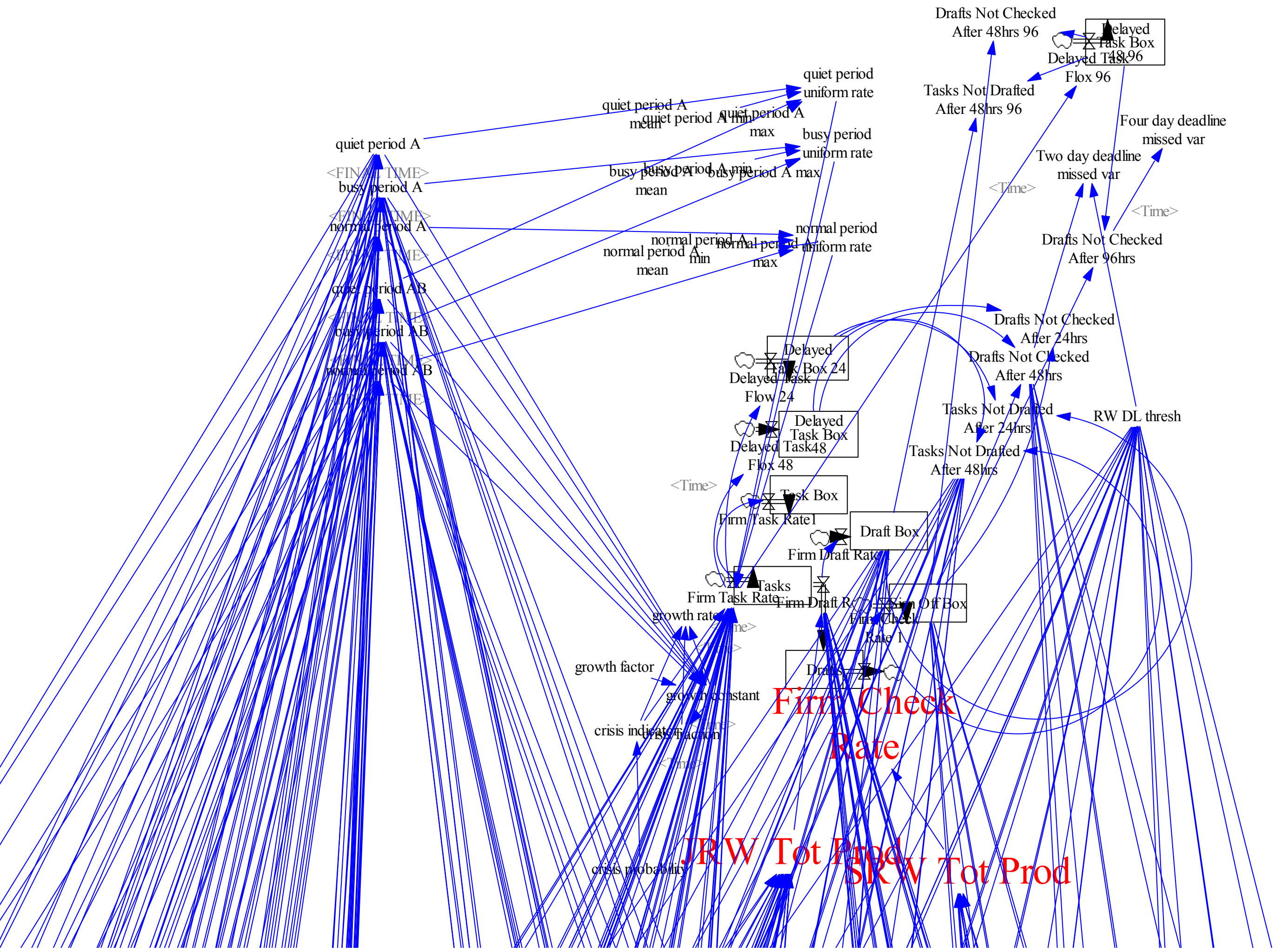


Figure D.4: Extract of Firm task rate, draft rate, check rate as modelled in Vensim

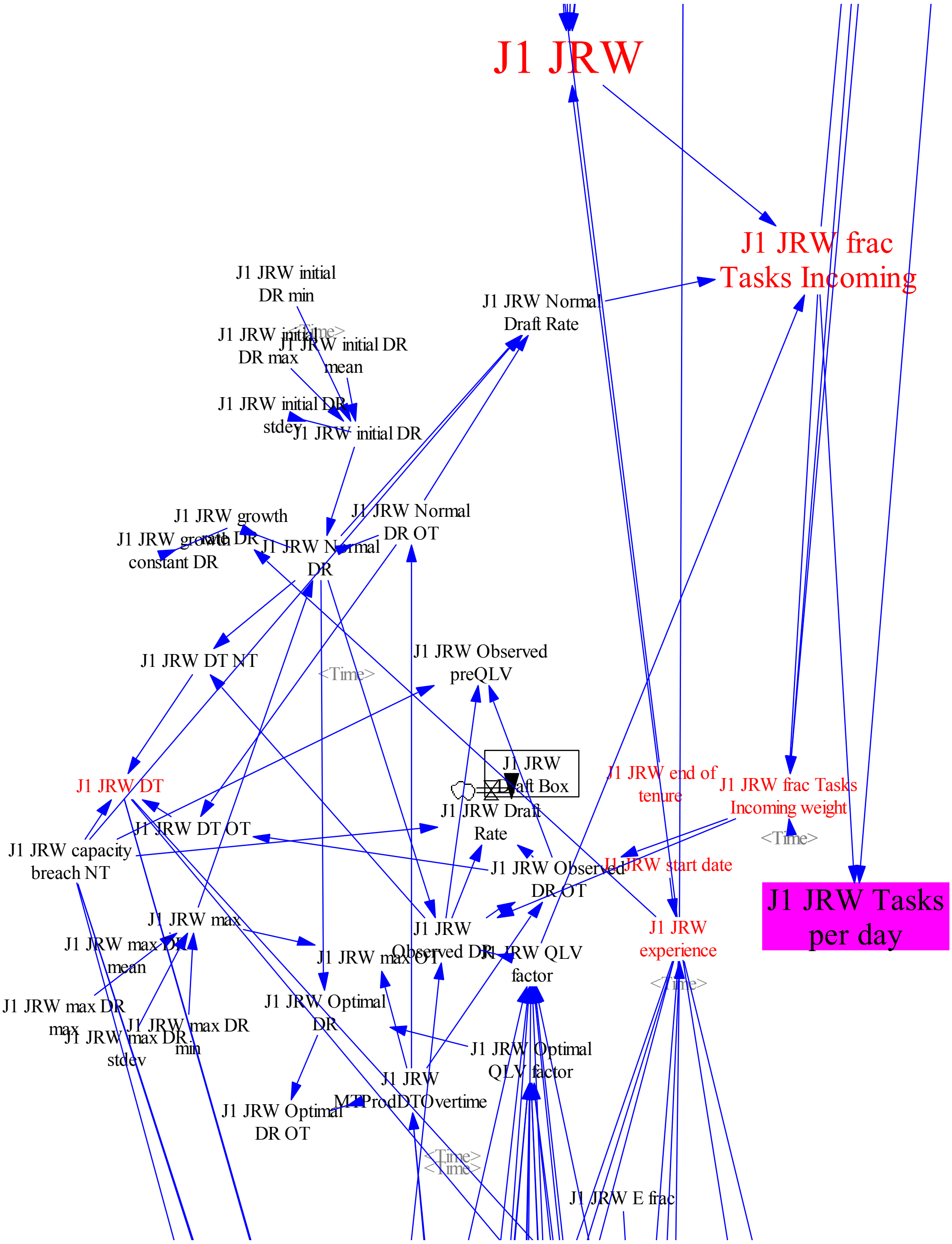


Figure D.5: Extract of J1 JRW quantitative modelling as modelled in Vensim

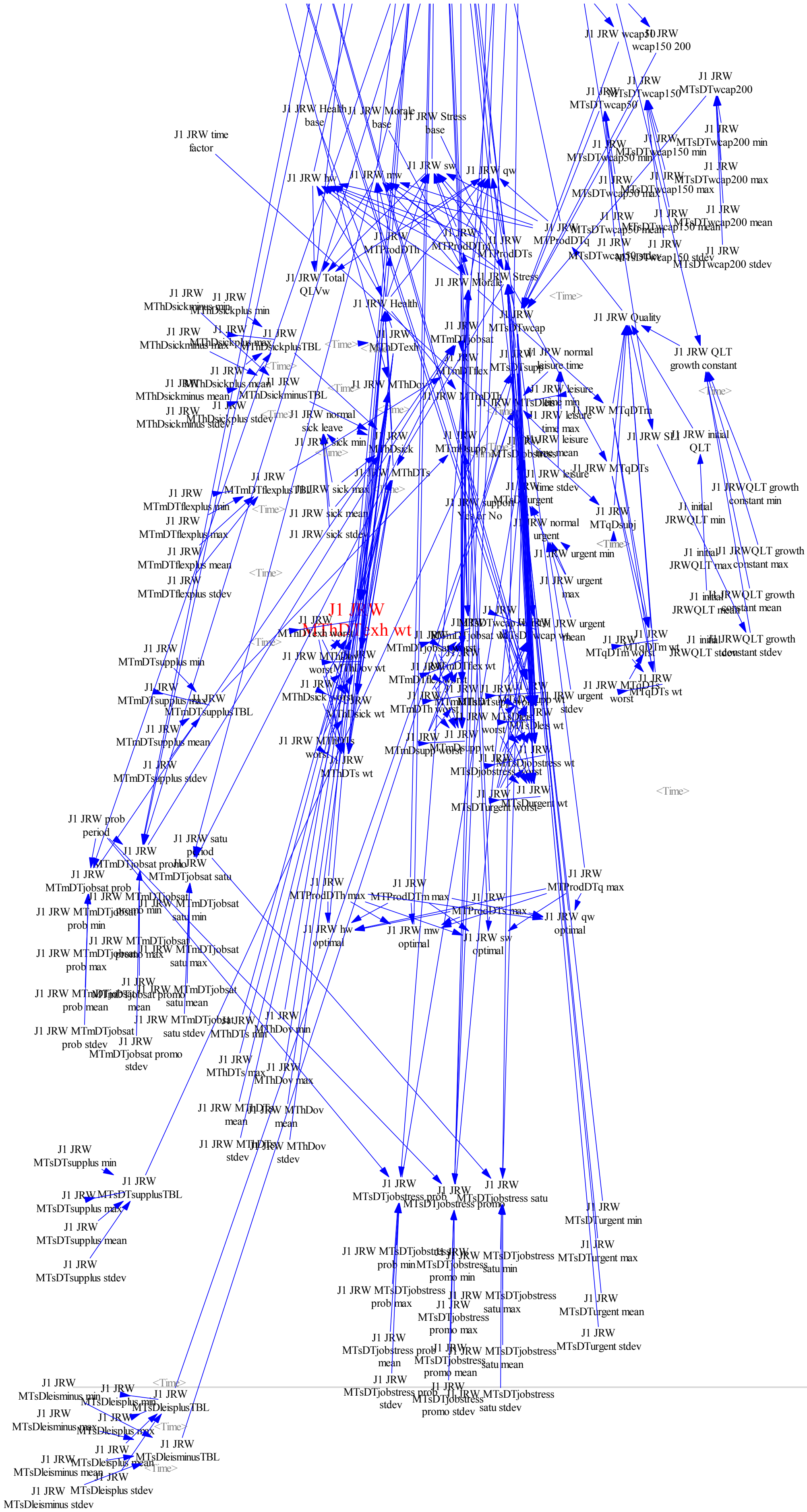

J1 JRW time factor
J1 JRW Health base
J1 JRW Morale base
J1 JRW Stress base
J1 JRW hw
J1 JRW mw
J1 JRW sw
J1 JRW qw
J1 JRW Total QLVw
J1 JRW Health
J1 JRW Morale
J1 JRW Stress
J1 JRW Quality
J1 JRW QLT growth constant
J1 JRW MThDTexh wt
J1 JRW MTsDTwcap
J1 JRW wcap150 200
J1 JRW MTsDTwcap50
J1 JRW MTsDTwcap150
J1 JRW MTsDTwcap200
J1 JRW MTProdDTh
J1 JRW MTProdDTq
J1 JRW MTProdDTs
J1 JRW normal sick leave
J1 JRW sick min
J1 JRW sick max
J1 JRW sick mean
J1 JRW sick stdev
J1 JRW normal leisure time
J1 JRW leisure time min
J1 JRW leisure time max
J1 JRW leisure time mean
J1 JRW leisure time stdev
J1 JRW normal urgent
J1 JRW urgent min
J1 JRW urgent max
J1 JRW urgent mean
J1 JRW urgent stdev
J1 JRW MTqDTm
J1 JRW MTqDTs
J1 JRW MTqDsubj
J1 JRW SEI
J1 JRW initial QLT
J1 JRW support Yes or No
J1 JRW prob period
J1 JRW satu period
J1 JRW MTmDTjobsat prob
J1 JRW MTmDTjobsat satu
J1 JRW MTmDTjobsatTBL
J1 JRW MTmDTflexplusTBL
J1 JRW MTmDTsupplusTBL
J1 JRW MThDsickplusTBL
J1 JRW MThDsickminusTBL
J1 JRW hw optimal
J1 JRW mw optimal
J1 JRW sw optimal
J1 JRW qw optimal
J1 JRW MTProdDTh max
J1 JRW MTProdDTm max
J1 JRW MTProdDTs max
J1 JRW MTProdDTq max
J1 JRW MTsDTjobstress prob
J1 JRW MTsDTjobstress promo
J1 JRW MTsDTjobstress satu
J1 JRW MTsDTurgent min
J1 JRW MTsDTurgent max
J1 JRW MTsDTurgent mean
J1 JRW MTsDTurgent stdev
J1 JRW MTsDTsupplusTBL
J1 JRW MTsDTsupplus min
J1 JRW MTsDTsupplus max
J1 JRW MTsDTsupplus mean
J1 JRW MTsDTsupplus stdev
J1 JRW MTsDleisplusTBL
J1 JRW MTsDleisminusTBL
J1 JRW MTsDleisplus stdev
J1 JRW MTsDleisminus stdev
<Time>

Figure D.6: Figure D.2: Extract of J1 JRW qualitative modelling as modelled in Vensim

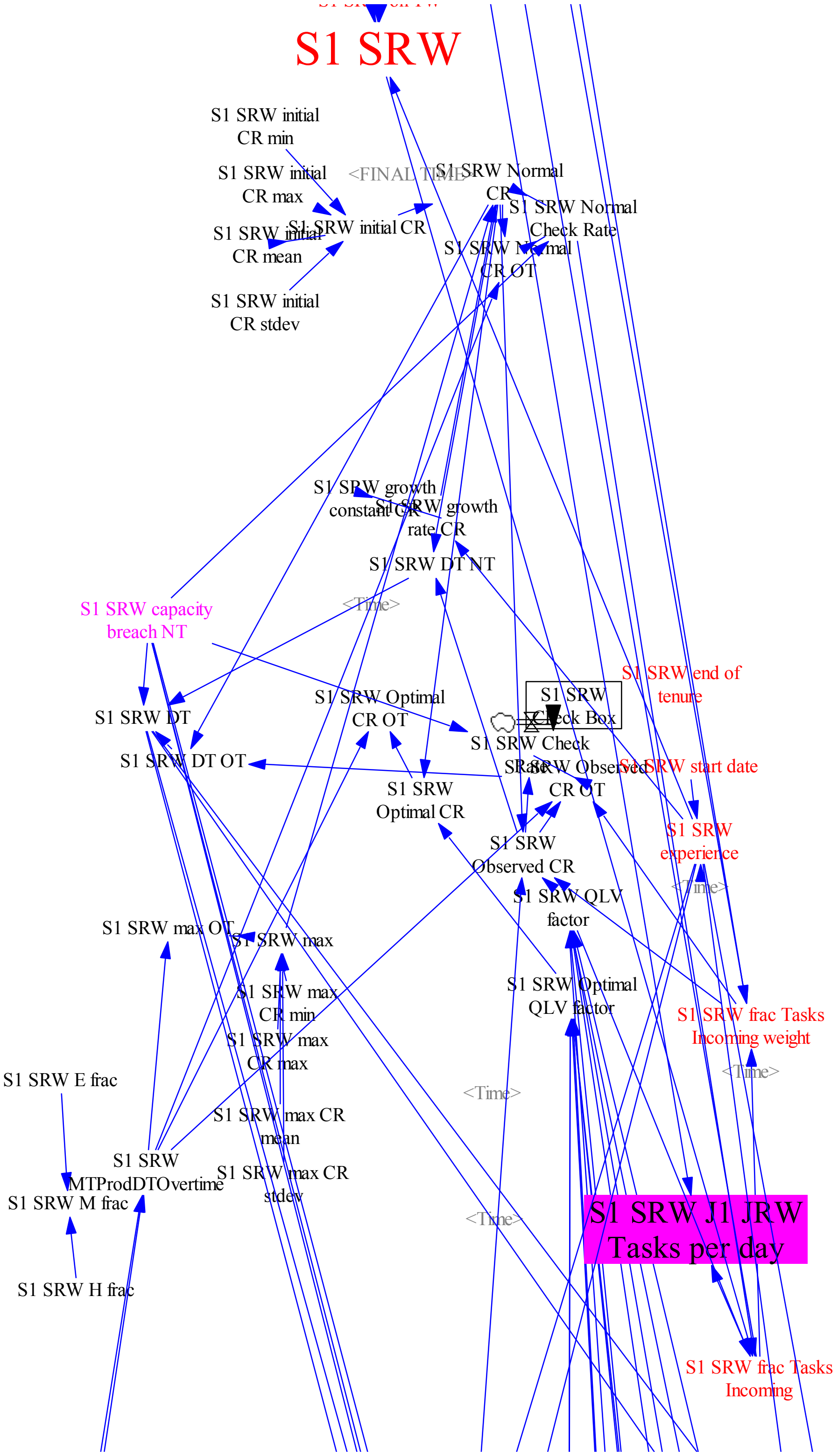
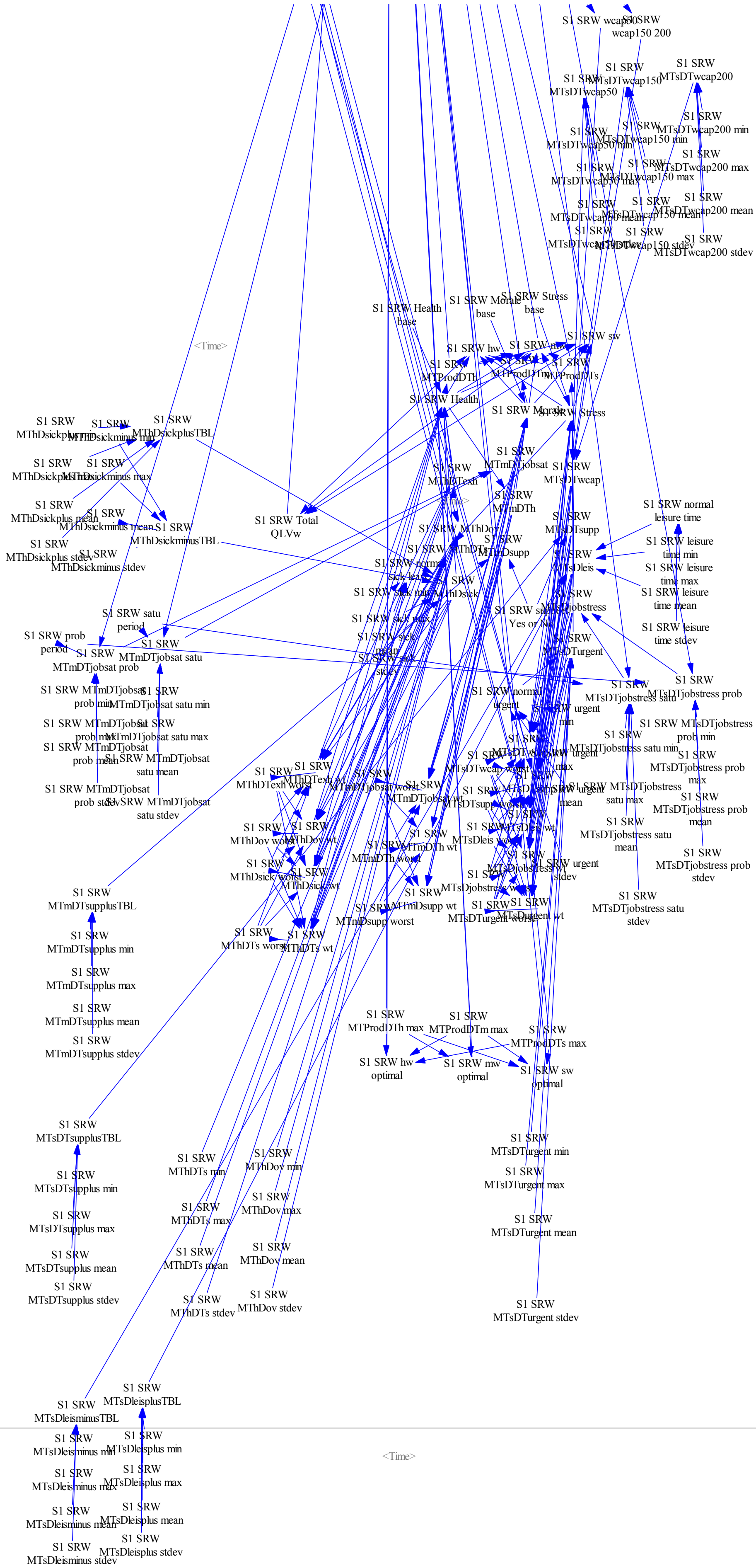


Figure D.7: Extract of S1 SRW quantitative modelling as modelled in Vensim



S1 SRW Health base
S1 SRW Morale base
S1 SRW Stress base
S1 SRW hw
S1 SRW sw
S1 SRW MTProdDTh
S1 SRW MTProdDTs
S1 SRW Health
S1 SRW Morale
S1 SRW Stress
S1 SRW MTsDTwcap50
S1 SRW MTsDTwcap150
S1 SRW MTsDTwcap200
S1 SRW MTsDTwcap200 min
S1 SRW MTsDTwcap200 max
S1 SRW MTsDTwcap200 mean
S1 SRW MTsDTwcap200 stdev
<Time>
S1 SRW MThDsickplusTBL
S1 SRW MThDsickminusTBL
S1 SRW MThDsickplus mean
S1 SRW MThDsickplus stdev
S1 SRW MThDsickminus stdev
S1 SRW Total QLVw
S1 SRW MTmDTjobsat
S1 SRW MTsDTwcap
S1 SRW MThDTexh
S1 SRW MTmDTh
S1 SRW MTsDTsupp
S1 SRW MThDsupp
S1 SRW MTsDleis
S1 SRW MTsDTjobstress
S1 SRW MTsDTurgent
S1 SRW normal leisure time
S1 SRW leisure time min
S1 SRW leisure time max
S1 SRW leisure time mean
S1 SRW leisure time stdev
S1 SRW satu period
S1 SRW prob period
S1 SRW MTmDTjobsat satu
S1 SRW MTmDTjobsat prob
S1 SRW MTmDTjobsat satu min
S1 SRW MTmDTjobsat satu max
S1 SRW MTmDTjobsat satu mean
S1 SRW MTmDTjobsat satu stdev
S1 SRW MTmDTjobsat prob min
S1 SRW MTmDTjobsat prob max
S1 SRW MTmDTjobsat prob mean
S1 SRW MTmDTjobsat prob stdev
S1 SRW MTsDTjobstress satu
S1 SRW MTsDTjobstress prob
S1 SRW MTsDTjobstress prob min
S1 SRW MTsDTjobstress prob max
S1 SRW MTsDTjobstress prob mean
S1 SRW MTsDTjobstress prob stdev
S1 SRW MTsDTjobstress satu min
S1 SRW MTsDTjobstress satu max
S1 SRW MTsDTjobstress satu mean
S1 SRW MTsDTjobstress satu stdev
S1 SRW normal urgent
S1 SRW urgent stdev
S1 SRW MThDTexh worst
S1 SRW MThDov worst
S1 SRW MThDov wt
S1 SRW MThDsick worst
S1 SRW MThDsick wt
S1 SRW MThDTs worst
S1 SRW MThDTs wt
S1 SRW MTmDTh worst
S1 SRW MTmDTh wt
S1 SRW MTmDsupp worst
S1 SRW MTmDsupp wt
S1 SRW MTsDTurgent worst
S1 SRW MTsDTurgent wt
S1 SRW MTmDTsupplusTBL
S1 SRW MTmDTsupplus min
S1 SRW MTmDTsupplus max
S1 SRW MTmDTsupplus mean
S1 SRW MTmDTsupplus stdev
S1 SRW MTProdDTh max
S1 SRW MTProdDTm max
S1 SRW MTProdDTs max
S1 SRW hw optimal
S1 SRW mw optimal
S1 SRW sw optimal
S1 SRW MTsDTsupplusTBL
S1 SRW MTsDTsupplus min
S1 SRW MTsDTsupplus max
S1 SRW MTsDTsupplus mean
S1 SRW MTsDTsupplus stdev
S1 SRW MThDTs min
S1 SRW MThDTs max
S1 SRW MThDTs mean
S1 SRW MThDTs stdev
S1 SRW MThDov min
S1 SRW MThDov max
S1 SRW MThDov mean
S1 SRW MThDov stdev
S1 SRW MTsDTurgent min
S1 SRW MTsDTurgent max
S1 SRW MTsDTurgent mean
S1 SRW MTsDTurgent stdev
S1 SRW MTsDleisminusTBL
S1 SRW MTsDleisplusTBL
S1 SRW MTsDleisminus min
S1 SRW MTsDleisminus max
S1 SRW MTsDleisminus mean
S1 SRW MTsDleisminus stdev
S1 SRW MTsDleisplus min
S1 SRW MTsDleisplus max
S1 SRW MTsDleisplus mean
S1 SRW MTsDleisplus stdev
<Time>

Figure D.8: Extract of S1 SRW qualitative modelling as modelled in Vensim

Questionnaire given to RWs:

What was your initial productivity (reports/day and reports/week) during your probation period (i.e. first months on the job)?

What is your current productivity (reports/day and reports/week)?

How many months have you been employed at this firm?

What would you say was your maximum productivity you were capable of drafting/checking during your probation period?

What would you say is your maximum productivity you are capable of drafting/checking at present?

As per our discussion, please state the possible qualitative variables that you believe would affect productivity.

QLV Questions

As per our discussion, please state the 3 qualitative variables that would affect your productivity the most? In addition, please state possible variables that could affect the 3 variables you have chosen.

Salary A fixed regular payment, typically paid on a monthly basis but often expressed as an annual sum, made by an employer to an employee, especially a professional or white worker.

Example: *He received a salary of £24,000*

Leisure Time when one is not working or occupied; free time. Use of free time for enjoyment. Opportunity afforded by free time to do something.

Example: *writers with enough leisure to practise their art*

Development The process of developing or being developed.

Example: *she traces the development of the novel the paintings provide evidence of his artistic development*

Qualification A pass of an examination or an official completion of a course, especially one conferring status as a recognized practitioner of a profession or activity.

Example: *I left school at 15 with no qualifications*

Experience The knowledge or skill acquired by a period of practical experience of something, especially that gained in a particular profession.

Example: *You should have the necessary experience in health management*

Health (burnout) Physical or mental collapse caused by overwork or stress

Example: *high levels of professionalism which may result in burnout*

Morale - The confidence, enthusiasm, and discipline of a person or group at a particular time

Example: *the team's morale was high*

Stress - A state of mental or emotional strain or tension resulting from adverse or demanding circumstances

Example: *he's obviously under a lot of stress*

As per our discussion, please estimate the % change in Y brought about by X being at the following levels.

Health%	% change in Productivity
0	
20	
40	
60	
80	0%
100	

e.g. when my health levels are 40%, my productivity changes by ...%

...where, Health levels:

$X \leq 20\%$ - very tired

$X \leq 40\%$ - tired and in need of a break

$X \leq 60\%$ - tired but ok

$X \leq 80\%$ - marginally tired

$X \leq 100\%$ - not so tired

Stress%	% change in Productivity
0	
20	
40	
60	0%
80	
100	

e.g. when my stress levels are 40%, my productivity changes by ...%

...where, Stress levels:

$X \leq 20\%$ - not so stressed

$X \leq 40\%$ - marginally stressed

$X \leq 60\%$ - stressed but ok

$X \leq 80\%$ - stressed and in need of a break

$X \leq 100\%$ - very stressed

Morale%	% change in Productivity
0	
20	
40	
60	0%
80	
100	

e.g. when my morale levels are 40%, my productivity changes by ...%

...where, Morale levels:

$Y \leq 20\%$ - no motivation

$Y \leq 40\%$ - not so motivated/happy

$Y \leq 60\%$ - marginally motivated/happy

$Y \leq 80\%$ - Motivated/happy

$Y \leq 100\%$ - feeling very motivated/happy

Quality%	% change in Productivity
0	
50	
70	
90	0%
95	
100	

Health

As per our discussion, please estimate the % change in health at the end of the indicated period due to exhaustion.

Period	% change in Health
First quiet period of the year	
Second quiet period of the year	
First normal period of the year	
Second normal period of the year	
First busy period of the year	
Second busy period of the year	

e.g. at the end of the first quiet period of the year I feel as if health has deceased/increased by...% due to exhaustion

As per our discussion, please estimate the % change in health when you work overtime.

As per our discussion, please estimate the average number of sick leave days you take per year.

As per our discussion, please estimate the % change in health should you find yourself with less sick days than average.

As per our discussion, please estimate the number of sick days that would cause a negative impact on health, and estimate the percentage change is health that would come with having this number of sick leave days.

As per our discussion, please estimate the % change in health when stress levels are at +80%

Morale

As per our discussion, please estimate the % change in morale at (a) the beginning of your probation period (b) the beginning of a promotion (c) when you feel there is not more you can learn or develop from your job.

As per our discussion, please estimate the % change in morale if you were allowed flexitime.

As per our discussion, please estimate the % change in morale brought about by health being at the following levels.

Health%	% change in Morale
0	
20	
40	
60	
80	
100	

e.g. when my health levels are 40%, my morale changes by ...%

...where, Health levels:

$X \leq 20\%$ - very tired

$X \leq 40\%$ - tired and in need of a break

$X \leq 60\%$ - tired but ok

$X \leq 80\%$ - marginally tired

$X \leq 100\%$ - not so tired

As per our discussion, please estimate the % change in morale after receiving support from the life coach.

Stress

As per our discussion, please estimate the % change in stress when your work capacity is (a) 50% (b) 150% (c) 200%

As per our discussion, please estimate the % change in stress after receiving support from the life coach.

As per our discussion, please estimate the average number of leisure hours you have per day.

As per our discussion, please estimate the % change in stress should you find yourself with more leisure hours than average.

As per our discussion, please estimate the number of leisure hours that would cause a positive impact on stress (increase stress), and estimate the percentage change is stress that would come with having this number of leisure hours.

As per our discussion, please estimate the % change in stress at (a) the beginning of your probation period (b) the beginning of a promotion (c) when you feel there is not more you can learn or develop from your job.

As per our discussion, please estimate the percentage of tasks that are urgent that would cause a positive impact on stress (increase stress), and estimate the percentage change is stress that would come with having this percentage of tasks that are urgent.

Quality

What was your initial average quality level during your probation period (i.e. first months on the job)?

What is your current average quality level?

How many months have you been employed at this firm?

How long do you think it will take (months) for you to sign off reports?

As per our discussion, please estimate the % change in quality at the following levels of morale

Morale%	% change in quality
0	
20	
40	
60	
80	
100	

As per our discussion, please estimate the % change in quality at the following levels of stress

Stress%	% change in quality
0	
20	
40	
60	
80	
100	

Cognitive Mapping

Stages in building cognitive map:

1. By the time that the writer had requested to have a cognitive mapping session with management the writer had covered literature on cognitive mapping and its usefulness in aiding in business process modelling (Eden, 1994). The writer had also spent just over half a year studying the form's business process.
2. The writer had seen cognitive mapping as a tool that would assist in building the business process model. The cognitive mapping sessions would assist in setting out clearer objectives, and as a result facilitate in the model building phase as the models would be built taking into account management's perspective of the firm and the firm's process, and ensure that the models were pertinent to management's decision making needs.
3. Before requesting a meeting with management to hold the cognitive map session, the writer drafted a series of questions that he intended to ask management in order for the writer to build a cognitive map. The questions asked in the session are written out in Appendix D under the heading Cognitive Mapping. These questions focused on how the firm has grown over time, looking into capacity and workload. We looked at threats to the business and growth strategies that were adopted. We also wanted to get an idea of where management sees the firm in a few years' time.
4. In the third quarter of 2013 the writer sent out an email meeting request to management (managing director, president and vice president) of the firm requesting two one hour sessions for the purposes of building a cognitive map. In the email, the writer briefly described the cognitive mapping sessions as a tool to capture management's perspective of the firm as they have experienced it over the past few years, as well as capture their goals and aspirations from the onset of the firm, and how these have changes over time. The writer explained in the email that the cognitive map allows the writer to get a better understanding of the firm, as well as the firm's business process, and allows the writer to shape the objectives of the study more clearly given what management perceive to be key areas in the growth and development of the firm and its business process. The writer went on to attach the questions that he intended to ask management in the email.
5. The writer then received a meeting confirmation from the vice president of the firm, with the rest of management cancelling the request citing busy schedules.

6. The first cognitive mapping session with the vice president was held in his office, where the writer and the vice president held a question and answer session, which also led to a discussion, around the questions sent to management by the writer. The writer was noting down the key points from the session, a task that was relatively challenging as the writer had to ask the questions, lead the discussion, as well as note down responses. The task was made relatively easier given the vice president's patience, and willingness to repeat, as well as elaborate on his answers.
7. Below is an extract of some of the questions asked and answered (bullet points), with some of the answers altered in terms of names and personal information given.

How did the idea come about to build up MCA?

- *Started off as hobby for the current president's father.*
- *Would do calculations for RAF on the side whilst still managing direct of a big corporate firm (Contact president's father for more info).*
- *The work he did was not anything formal (not serious business).*
- *When the president's father retired from big corporate firm it became more formal as he began to make an income from it.*

What are some of the major gambles that you have had to take in order to get to where you are?

- *President had to leave secure job at a big corporate firm, with secure income steam, to a job where income generation was uncertain. Director also left secure employment to come help president look for sources of income (clients), initially working from abroad. Vice president also roped in to aid in looking for future revenue streams. As time went by the uncertainty around revenue became less and less.*
- *Vice president never imagined it getting to its current capacity, workload and income generation.*
- *Exposed to more risk now with bigger capacity (employees) and bigger client base.*
- *With initial increase in workforce president had to take on burden of report writing when the first and only two report writers were on study leave. Also increased workload meant more work for the two report writers, which increased chances of making mistakes with increase pressure to meet all deadlines. There was need to hire more report writers.*
- *There was a struggle to find actuaries and MCA decided to take gamble and hire non-actuarial recruits with no actuarial background (Vice president notes that this is biggest gamble MCA took that worked).*
- *Gamble around hiring non-actuarial recruits as president had to train them as well as do reports and still cover for the two report writers when they were on study leave.*

What were the major threats to the company when it was founded/growing? What are some of the major threats at the moment?

- *Not much of threat given the niche market MCA operates in, and president had skills set to do the job.*
- *But if no action was taken on sales side it was possible that competition would have taken the market share of clients.*
- *If product and service was not marketed the business would have shrunk and business would not have grown.*
- *Threat was not having adequate (quantity-wise) human resources to cope with volume whilst still meeting 48 hour turnaround time*
- *Threat of cash flow. President was not operations person (lacking invoicing skills). Vice president had to step in ad handle debt collections. No proper incoming system was in place and RAF clients took long to pay (sometimes not at all) due to incompetency in the RAF. Plaintiff attorneys had to wait for matter to be settled before they could pay MCA.*
- *MCA had to take loans to get cash flow going.*
- *Amended work was not being invoiced properly and clients complained about being billed twice (confusion round invoicing system). Vice president had to take trips to clients explaining invoicing system. Lead to a better invoicing system.*
- *Competition was not a huge threat as competition was not active in selling its service and product to the market.*
- *Current threat in that RAF will not live up to its service delivery agreement. New director was hired in order to ensure that RAF does live up to the agreement.*

9. After a week of compiling the answers from the session, the writer met again with the vice president to run over the answers the vice president had given. This session was brief as the vice president agreed on all the answers and elaborated further on a few of them.
10. The transcripts from the cognitive mapping session were later translated into the cognitive map, which was first drawn up by the writer and later revised with the aid of the Vice President. Below is the cognitive map that was drawn up. The map, as well as the written responses was forwarded to the rest of management via email, and they responded to say that they were happy with the map and had nothing new to add. It is possible that not much time was taken by the rest of management (president and director) to go over the responses and cognitive map, which could possibly mean that the cognitive mapping is heavily biased towards the perspective of the vice president. The data and information obtained to build the cognitive map would have been relatively more reliable and unbiased had the writer had the chance to hold a session with each of the senior managers.

Past

How did the idea come about to build up MCA?

What are some of the major gambles that you have had to take in order to get to where you are?

What were some of the expected/unexpected challenges faced over the years and how did you go about solving them?

What were the major threats to the company when it was founded/growing? What are some of the major threats at the moment?

What are the values of the business? What are some of the things you cannot compromise in terms of the values of the business ?

Can you detail the increase in capacity and work from foundation up to present time?

What has caused the increase in business?

What makes us stick out to our clients (price, turnaround time, etc)? Do you believe that there is a need to worry about competing actuarial firms?

What has caused loss of clients or approval ratings?

What are some of the qualities/skills set that have made productivity better?

Do you have a better idea of the type of people you need to hire now should there be a need?

What are some of the challenges you face at present and what are some of the main challenges you think you will face going forward?

Looking back 5 years, is this where you would have wanted to be? Looking forward 5 years, would you satisfied with where you are currently?

Where is the company most vulnerable internally currently in terms of day to day business, what could potentially setback the company?

In terms of capacity and work, where do you see that ending in terms of growth?

Please feel free to share more information that you would think would be helpful in terms of me understanding the firm better.

Other Questions

Questions asked to Administration Team

What duties do you do as the admin team?

Who trained you in the admin process?

How long did it take for you to grasp the tasking process?

Does your tasking time improve over time?

In terms of skill, what is the most vital skill required when tasking?

What are some of the key areas that you struggled with initially?

What are some of the areas you are still trying to cope with?

How much did previous experience help in grasping admin role at MCA?

Roughly how long does it take on average to task a task?

When is the busiest/quietest period for MCA? How many tasks come in during the day? How many tasks come in as urgent per day?

On average, how many tasks do each of you task per day?

Is it busier during the morning or afternoon?

Are there days that are particularly quiet/busy?

How often do you work overtime?

What are some of the daily problems you face as admin lady?

How much phone time do you spend per day?

What external factors negatively affect your productivity?

How much rework/re-tasking is done?

How has SharePoint improved tasking rate?

Has SharePoint affected tasking negatively in any way?

How much time is wasted on average (tasking and re-tasking) when internet or SharePoint is down?

What do you do on occasion when SharePoint or the internet is down?

Have any ideas been suggested to try improve admin, if need be?

Will SPEAR affect anything within the admin process? If yes, how?

What makes a perfect day for tasking?

JRW Questions

What duties do you do as JRWs?

Who trained you in the JRW process?

How long did it take for you to grasp the drafting process?

Does your drafting time improve over time?

What was the scariest part during your training?

In terms of skill, what is the most vital skill required when tasking?

What are some of the key areas that you struggled with initially?

What are some of the areas you are still trying to cope with?

How much did previous experience help in grasping JRW role at MCA?

How many urgent (per day) /E/M/H task would you say you do (fraction)?

Roughly how long does it take on average to draft a task (E/M/H)?

How many tasks do you draft per day?

How many tasks have missing or confusing information?

How many successful calls do you make per day for information?

How many tasks end up as waiting on?

Do you work better in the morning or afternoon?

How does a busy day affect your productivity or morale?

How does a quiet day affect your productivity or morale?

Do you work better under deadline or if matter is urgent?

Is it busier during the morning or afternoon?

Are there days, months that are particularly quiet/busy?

How often do you work overtime?

What are some of the daily problems you face as JRWs?

What's the worst thing that has happened as JRW?

How much phone time do you spend per day?

What external factors negatively affect your productivity?

How much checking and rechecking is done?

How often do you have to make your own corrections to your drafts? – About 50%.

Has SharePoint affected tasking negatively in any way?

What are some of the problems you face with SharePoint?

How often is internet down?

How much time is wasted on average (waiting on instructions) when internet or SharePoint is down?

What do you do on occasion when SharePoint or the internet is down?

Have any ideas been suggested to try improve RW process, if need be?

Will SPEAR affect anything within the RW process? If yes, how?

What makes a perfect day for JRWs?

What are/were your main motivations to improve in your work?

What demotivates/demotivated you?

Are there any duties that you do beyond what is required that improve the RW process?

Does seeing other people thrive motivate, demotivate you?

How as shifting hours affected productivity or the process? Is more work done when under shift? – Potential danger of working later than usual if on early shift.

SRW Questions

What duties do you do as SRWs?

Who trained you in the SRW process?

As a trainer, how much time (months) did you take to train new RWs?

How long did it take for you to grasp the checking process?

Does your checking time improve over time?

What was the scariest part during your training?

In terms of skill, what is the most vital skill required when checking?

What are some of the key areas that you struggled with initially?

What are some of the areas you are still trying to cope with?

How much did previous experience help in grasping SRW role at MCA?

How many urgent (per day) /E/M/H task would you say you do (fraction)?

Roughly how long does it take on average to check a task (E/M/H)?

How many drafts do you check per day?

How many tasks do you draft per day?

How many tasks do you draft from scratch and check for yourself? When do you draft reports?

Do you work better in the morning or afternoon?

How does a busy day affect your productivity or morale? How does a quiet day affect your productivity or morale? Do you work better under deadline or if matter is urgent?

On average, how many drafts do each of you check per day?

Is it busier during the morning or afternoon?

Are there days, months that are particularly quiet/busy?

How often do you work overtime?

What are some of the daily problems you face as SRWs?

What's the worst thing that has happened as SRW?

How much time is consumed helping out of other JRWs?

How much phone time do you spend per day?

What external factors negatively affect your productivity?

How much checking and rechecking is done? How often do you have to start a draft that has been draft from scratch?

Has SharePoint affected tasking negatively in any way?

What are some of the problems you face with SharePoint?

How much time is wasted on average (waiting on instructions/drafts) when internet or SharePoint is

down?

What do you do on occasion when SharePoint or the internet is down?

Have any ideas been suggested to try improve RW process, if need be?

What makes a perfect day for SRWs?

What are/were your main motivations to improve in your work? What demotivates/demotivated you?

Are there any duties that you do beyond required that improve the RW process?

Does seeing other people thrive motivate, demotivate you? What are your main motivations?

How as shifting hours affected productivity or the process? Is more work done when under shift?

Sce.	Task Rate	Role	Number of RWs	Draft Rate/ Check Rate	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 1	39.82	JRWDFT	10.0	39.80	39.73	39.88	61.41%	61.30%	61.52%	<0.01%	<0.01%	<0.01%	4.07%	3.88%	4.27%
		SRWCHK	5.0	39.80	39.73	39.88	54.52%	54.43%	54.60%	<0.01%	<0.01%	<0.01%			

Table D.2: Objective 3 - Scenario 1 - initial hiring of RWs without QLVS

Sce.	Task Rate	Role	Number of RWs	Draft Rate/ Check Rate	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 2	39.58	JRWSND	10.0	18.57	18.53	18.61	28.66%	28.60%	28.73%	<0.01%	<0.01%	<0.01%	1.4%	1.30%	1.54%
		SRWSND	5.0	21.00	20.95	21.06	28.66%	28.60%	28.73%	<0.01%	<0.01%	<0.01%			

Table D.3: Objective 3 - Scenario 2 - initial hiring of RWs without QLVS

Sce.	Task Rate	Role	Number of RWs	Draft Rate/ Check Rate	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 3	39.69	JRWDFT	5.0	13.66	13.63	13.69	42.17%	42.08%	42.26%	<0.01%	<0.01%	<0.01%	3.88%	3.69%	4.07%
		SRWCHK	3.0	13.66	13.63	13.69	31.40%	31.34%	31.47%	<0.01%	<0.01%	<0.01%			
		RWSND	7.0	26.03	25.97	26.09	30.12%	30.06%	30.19%	<0.01%	<0.01%	<0.01%			

Table D.4: Objective 3 - Scenario 3 - initial hiring of RWs without QLVS

Sce.	Task Rate	Role	Number of RWs	95% CI		Draft/ Check Rate	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 4A	40.10	JRWSND	5.12	5.10	5.13	17.30	17.23	17.37	54.25%	54.07%	54.42%	1.41%	1.30%	1.51%	7.39%	7.13%	7.64%
		SRWSND	3.09	3.07	3.10	22.63	22.55	22.72	52.94%	52.76%	53.12%	1.41%	1.30%	1.51%			

Table D.5: Objective 4 - Scenario 1 - RWer turnover (without QLVS)

Sce.	Role	Draft Rate/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed
Sce. 4A (p-value)	JRWSND	0.28	0.02	0.00	0.38
	SRWSND	0.01	0.00	0.00	

Table D.6: Objective 4 - Scenario 1 - RWer turnover p-values

Sce.	Task Rate	Role	Number of RWs	95% CI		Draft/ Check Rate	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 4B	40.10	JRWSND	5.12	5.10	5.13	17.30	17.23	17.37	54.25%	54.07%	54.42%	1.41%	1.30%	1.51%	7.39%	7.13%	7.64%
		SRWSND	3.09	3.07	3.10	22.63	22.55	22.72	52.94%	52.76%	53.12%	1.41%	1.30%	1.51%			

Figure D.9: Objective 4 - Scenario 2 - RWer turnover (without QLVS)

Sce.	Role	Draft Rate/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed
Sce. 4B (p-value)	JRWSND	<0.01	<0.01	<0.01	<0.01
	SRWSND	<0.01	<0.01	<0.01	<0.01

Figure D.10: Objective 4 - Scenario 2 - RWer turnover p-values

Sce.	Task Rate	Role	Number of RWs	95% CI		Draft/ Check Rate	95% CI		% Days on Flexi	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 5A	39.68	JRWSND	10.00	-	-	18.82	18.78	18.86	-	-	-	29.05%	28.99%	29.11%	<0.01%	-	-	3.22%	3.05%	3.39%
		SRWSND	5.00	-	-	20.86	20.81	20.91	-	-	-	28.52%	28.46%	28.59%	<0.01%	-	-			

Table D.7: Objective 5 - Scenario 1 - RWer flexitime (without QLVS)

Sce.	Role	Draft Rate/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed
Sce. 5A (p-value)	JRWSND	<0.01	<0.01	-	-
	SRWSND	<0.01	0.50	-	

Table D.8: Objective 5 - Scenario 1 - RWer flexitime p-values

Sce.	Task Rate	Role	Number of RWs	95% CI		Draft/ Check Rate	95% CI		% Days on Flexi	95% CI		% W/C	95% CI		% Days O/T worked	95% CI		% Days D/L missed	95% CI	
Sce. 5B	39.68	JRWSND	5.10	5.08	5.11	12.07	12.04	12.11	48.11%	47.61%	48.60%	36.72%	36.53%	36.91%	<0.01%	-	-	2.65%	2.49%	2.81%
		SRWSND	5.00	-	-	27.60	27.53	27.68	-	-	-	37.80%	37.70%	37.89%	<0.01%	-	-			

Figure D.11: Objective 5 - Scenario 2 - RWer flexitime (without QLVS)

Sce.	Role	Draft Rate/ Check Rate	% W/C	% Days O/T worked	% Days D/L missed
Sce. 5B (p-value)	JRWSND	<0.01	<0.01	-	-
	SRWSND	<0.01	0.50	-	

Figure D.12: Objective 5 - Scenario 2 - RWer flexitime p-value

Appendix E. Examples of Loops

E1: J1 JRW MTProdDTQLVs – start of loop

1. J1 JRW Observed DR
2. J1 JRW wcap
3. J1 JRW wcap150 200
4. J1 JRW MTs DTwcap
5. J1 JRW MTs Durgent wt
6. J1 JRW Stress
7. J1 JRW MThDTs
8. J1 JRW Health
9. J1 JRW MTmDTh
10. J1 JRW MTmDTflex wt
11. J1 JRW Morale
12. J1 JRW MTqDTm
13. J1 JRW Quality
14. J1 JRW MTProdDTq

E2: S1 SRW MTProdDTQLVs – start of loop

1. S1 SRW Observed CR
2. S1 SRW Check Rate
3. SRW Tot Prod
4. Firm Draft Rate
5. Firm Draft Rate 1
6. Draft Box
7. Tasks Not Drafted After 48hrs
8. S1 SRW capacity breach NT
9. S1 SRW MThDov
10. S1 SRW MThDov wt
11. S1 SRW Health
12. S1 SRW MTProdDTh

E3: JRW MTProdDTH - start of loop

1. J1 JRW hw
2. J1 JRW MTProdDTQLVs
3. J1 JRW frac Tasks Incoming
4. J1 JRW frac Tasks Incoming weight
5. J1 JRW Observed DR
6. J1 JRW Draft Rate
7. JRW Tot Prod
8. Firm Check Rate
9. Firm Check Rate 1
10. Sign Off Box
11. Drafts Not Checked After 48hrs
12. S3 S1 SRW capacity breach NT
13. S3 S1 SRW wcap
14. S3 S1 SRW MTsDTsupp wt

15. S3 S1 SRW Stress
16. S3 S1 SRW hw
17. S3 S1 SRW MTProdDTQLVs
18. S3 S1 SRW Observed CR
19. S3 S1 SRW Check Rate
20. SRW Tot Prod
21. Firm Draft Rate
22. Firm Draft Rate 1
23. Draft Box
24. Tasks Not Drafted After 48hrs
25. J1 JRW capacity breach NT
26. J1 JRW wcap
27. J1 JRW wcap50
28. J1 JRW MTs DTwcap
29. J1 JRW MTs DTsupp wt
30. J1 JRW Stress
31. J1 JRW MThDTs
32. J1 JRW MThDov wt
33. J1 JRW Health

E4: SRW MTProdDTH – start of loop

1. S1 SRW hw
2. S1 SRW MTProdDTQLVs
3. S1 SRW frac Tasks Incoming
4. RW frac Tasks Incoming
5. J1 JRW frac Tasks Incoming weight
6. J1 JRW Observed DR
7. J1 JRW Draft Rate
8. JRW Tot Prod
9. Firm Draft Rate
10. Firm Draft Rate 1
11. Draft Box
12. J12 J1 JRW
13. Number of RWs for weight
14. S1 SRW frac Tasks Incoming weight
15. S1 SRW Observed CR
16. S1 SRW wcap NT
17. S1 SRW wcap
18. S1 SRW wcap50
19. S1 SRW MTsDTwcap
20. S1 SRW Stress
21. S1 SRW MThDTs
22. S1 SRW MThDov wt
23. S1 SRW Health

E5: JRW MTProdDTM – start of loop

1. J1 JRW hw
2. J1 JRW MTProdDTQLVs
3. J1 JRW Observed DR

4. J1 JRW wcap NT
5. J1 JRW wcap
6. J1 JRW wcap150 200
7. J1 JRW MTs DTwcap
8. J1 JRW MTs DTwcap wt
9. J1 JRW Stress
10. J1 JRW MThDTs
11. J1 JRW MThDTs wt
12. J1 JRW Health
13. J1 JRW MTmDTh
14. J1 JRW MTmDTflex wt
15. J1 JRW Morale

E6: SRW MTProdDTM – start of loop

1. S1 SRW hw
2. S1 SRW MTProdDTQLVs
3. S1 SRW frac Tasks Incoming
4. S1 SRW frac Tasks Incoming weight
5. S1 SRW Observed CR OT
6. S1 SRW wcap OT
7. S1 SRW wcap
8. S1 SRW wcap150 200
9. S1 SRW MTsDTwcap
10. S1 SRW MTsDTsupp wt
11. S1 SRW Stress
12. S1 SRW MThDTs
13. S1 SRW Health
14. S1 SRW MTmDTh
15. S1 SRW MTmDTh wt
16. S1 SRW Morale

E9: JRW MTProdDTS – start of loop

1. J1 JRW hw
2. J1 JRW MTProdDTQLVs
3. J1 JRW frac Tasks Incoming
4. J1 JRW frac Tasks Incoming weight
5. J1 JRW Observed DR
6. J1 JRW Draft Rate
7. JRW Tot Prod
8. Firm Check Rate
9. Firm Check Rate 1
10. Sign Off Box
11. Drafts Not Checked After 48hrs
12. S3 S1 SRW capacity breach NT
13. S3 S1 SRW wcap
14. S3 S1 SRW MTsDTsupp wt
15. S3 S1 SRW Stress
16. S3 S1 SRW hw
17. S3 S1 SRW MTProdDTQLVs

18. S3 S1 SRW frac Tasks Incoming
19. RW frac Tasks Incoming
20. S1 SRW frac Tasks Incoming weight
21. S1 SRW Observed CR
22. S1 SRW Check Rate
23. SRW Tot Prod
24. Firm Draft Rate
25. Firm Draft Rate 1
26. Draft Box
27. Tasks Not Drafted After 48hrs
28. J1 JRW capacity breach NT
29. J1 JRW wcap
30. J1 JRW wcap150 200
31. J1 JRW MTs DTwcap
32. J1 JRW MTs Djobstress wt
33. J1 JRW Stress

E8: SRW MTProdDTS – start of loop

1. S1 SRW hw
2. S1 SRW MTProdDTQLVs
3. S1 SRW frac Tasks Incoming
4. RW frac Tasks Incoming
5. J1 JRW frac Tasks Incoming weight
6. J1 JRW Observed DR
7. J1 JRW Draft Rate
8. JRW Tot Prod
9. Firm Draft Rate
10. Firm Draft Rate 1
11. Draft Box
12. J11 J1 JRW
13. Number of RWs
14. S4 S1 SRW frac Tasks Incoming weight
15. S4 S1 SRW Observed CR
16. S4 S1 SRW Observed CR OT
17. S4 S1 SRW Check Rate
18. SRW Tot Prod
19. Firm Check Rate
20. Firm Check Rate 1
21. Sign Off Box
22. S1 SRW
23. S1 SRW frac Tasks Incoming weight
24. S1 SRW Observed CR
25. S1 SRW wcap NT
26. S1 SRW wcap
27. S1 SRW MTsDleis wt
28. S1 SRW Stress

E9: JRW MTProdDTQLT – start of loop

1. J1 JRW MTProdDTQLVs

2. J1 JRW Observed DR
3. J1 JRW Observed DR OT
4. J1 JRW wcap OT
5. J1 JRW wcap
6. J1 JRW MTsDTsupp wt
7. J1 JRW Stress
8. J1 JRW MThDTs
9. J1 JRW MThDsick wt
10. J1 JRW Health
11. J1 JRW MTmDTh
12. J1 JRW MTmDTh wt
13. J1 JRW Morale
14. J1 JRW MTqDTm
15. J1 JRW MTqDTm wt
16. J1 JRW Quality